DEVELOPMENT AND IMPACT OF FUEL ECONOMY STANDARDS AND LABELS FOR LIGHT DUTY VEHICLES IN IRAN

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ABSTRACT

It was five years ago that Iranian government implemented various policies and programs such as applying quote on petrol consumption and changing the policies of subsidizing of petrol for optimization of fuel consumption in the transportation sector. At this time more than 58.4% of the total amount of oil products is consumed in the transportation section. The light duty vehicles consume around 56.5% of the fuel in transportation sector in Iran. Fuel saving initiatives such as the fuel economy standards and labels program for motor vehicles in transportation section has been applied in many developed countries around the world.

In This study all the efforts are putted to grow a fuel economy standards program according to survey data from motor vehicles in transportation sector in Iran. A fuel economy label for Iranian cars is also built up to make sure that consumers are conscious concerning the fuel consumption of motor vehicles and will facilitate for easier evaluation among automobiles. And as a foundation of the fuel economy standards programs, a test procedure is chosen from present procedures to measure motor vehicles fuel consumption especially for motor vehicles which are locally produced. This research has also investigated the influence of executing the fuel economy standards and labels program from the perception of the fuel savings, economic savings and in addition the influence on the environment.

The number of light duty vehicles in Iran has swiftly increased from approximately 3 million in 1998 to 8.7 million in 2008. Because of this growing quantity of motor vehicles in the country, lots of profit will come for the society as well as the environment by implementing of the fuel economy standards and labels program. By execution of the program around 23.9 billion liters of fuel is expected to be saved from 2013 to 2018. This means savings about 167,781 billion Rials in the bill and decrease of approximately 46.2 million tons of carbon dioxide emission.

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LIST OF SYMBOLS AND ABBREVIATIONS

AFI_i	Annual fuel economy ratings improvement in year i(%)
AS_I	Applicable stock in year i
ANS_i	Annualized net savings in year i
AS_{i-1}	Applicable stock in year i-1
BFC_s	Baseline fuel consumption (standard) (liters/year)
BFC_l	Baseline fuel consumption (label) (liters/year)
BFC_{YSC}	Baseline fuel consumption in the year of survey (liters/year)
BS_i	Bill savings in year i (Rials)
CRF	Capital recovery factor
d	Interest rate per year(%)
Em_p	Emission type p for a unit liter (kg/lit)
FC_i	Fuel consumption in year i (liters)
FER_i	Fuel economy rating in year i
FER_{i-1}	Fuel economy rating in year i-1
FER_{STD}	Fuel economy rating in year standards enacted
FER_{Ysc}	Fuel economy rating in year survey is conducted
FER	Fuel economy rating
FS_i	Fuel savings in year i (liters)
IC	Incremental cost of motor vehicle (Rials)
IIC_s	Initial incremental cost fuel efficient motor vehicle (Rials)
L	Lifespan of motor vehicle (years)
LCC	Life cycle cost (Rials)
FC_L	Label fuel consumption (liters/year)
MC	Annual maintenance cost (Rials)

N	Lifetime (years)
Nv_i	Number of motor vehicles in year i
Nv_{i-1}	Number of vehicles in year i-1
Nv_{i-L}	Number of vehicles in year i-L
η_s	Percentage fuel economy standards improvement of motor vehicle(%)
OC	Annual operating cost (Rials)
PC	Investment costs (Rials)
$PV(ANS_i)$	Present value of annualized net savings in year i (Rials)
PWF	Present worth factor
PF	Fuel Price (Rials)
PC	Investment cost (Rials)
r	discount rate(%)
SFC_{MV}	Standards fuel consumption of motor vehicles (liters/year)
Sh_i	Shipment in year i
SF_i	Scaling factor in year i
SSF_i	Shipment survival factor in year i
T	The target year of program
TI_S	Total fuel economy improvement(%)
UFS_s	Initial unit fuel savings (liters/year)
UFC_i	Unit fuel savings in year i (liters/year)
Ym	Annual mileage of motor vehicle (km)
Yse_i	Year of standards enacted of motor vehicle
Y_{SC}	Year survey conducted
Ysh_i	Year i of shipment of motor vehicle
Ydr	Year of discount rate base
%STD	Percentage Standards Improvement(%)

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CHAPTER 1

INTRODUCTION

One of the most important sectors is transportation. This sector contributes the big amount of fuel and energy consumption. The increase of using vehicles is unavoidable in any developing country and with the growth of the transportation system, the usage of depleting fuels which have negative impacts on the environment are increased. Generally, the major consumed fuel in the transportation system is fossil fuel. The main fuel consumption in the transportation sector of Iran is also gasoline, diesel. However, patterns of excessive production of greenhouse gases have been numerously studied, but these activities do not play any role in the production of millions of tons of greenhouse gases per year. Therefore, restrictions and guidelines should be put to community resources for preserving non-renewable energy for our future generations. In order to control the huge use of fossil fuel and to reduce the emissions, many methods have been suggested by scientists and researcher (Saidur, Masjuki et al. 2005; Mazandarani, Mahlia et al. 2010). One of the strategies is to optimize the energy consumption (Abdelaziz, Saidur et al. 2011; Saidur, Atabani et al. 2011). The other important suggested method is to use renewable energy sources (Fadai 2007; Mohammadnejad, Ghazvini et al. 2011). The implementation of energy policy is an appropriate and effective strategy to provide guidance that helps Iran to reduce overall greenhouse gas emissions. As a result, the implementation of energy policy will cause a reduction of energy consumption and have economic benefits. It also causes improve products for the international competition.

Fuel economy standards and labels have become a common policy in many countries and regions around the world. Fuel economy is defined as the measured average mileage traveled by vehicle per consumption of a gallon of gasoline (or equivalent in other fuels) in accordance with the evaluation protocol and testing. The fuel economy standard has been determined as the minimum level of fuel economy that motor vehicles must meet before it is legally sold. With the fuel economy standards, motor vehicles with high fuel consumption will be removed from the market and as a result, it will help the vehicle Iran to reduce overall greenhouse gas emissions and improve competitiveness of motor vehicles in the international arena.

Meanwhile, Mahlia defines an energy label which is voluntary or mandatory, that is attached to products or their packaging contains information regarding energy efficiency or energy product. This label is a tool to impact on vehicle manufacturers to take care about the fuel efficiency and it also enables customers to compare fuel economy vehicles on the market (Mahlia, Masjuki et al. 2002). Fuel economy politics, have become a major public program for developed countries around the world. The countries which implemented the fuel economy standards for motor vehicles are trying to enact the laws cause even higher fuel efficiency for motor vehicles; so there are some reasons behind this policy. Some of the advantages behind this policy are: causing the highly competitive industrial, high increase of the motor vehicles technologies and energy saving which causes bill saving and also positive effect on the environment.

1.1 Background

In order to implement the fuel economy standards and labels for light duty vehicle in Iran, the energy scenario of Iran (Mohammadnejad, Ghazvini et al. 2011) and the Iran energy policies (IIES 2010; Power 2010) are represented as background in this section.

1.1.1 Iran energy scenario

Iran is located in southwest of Asia with a total area of 1,648,195 km^2. The population of Iran increased from 61.83 million to 71.74 million during the years 1998 to 2008 (Iran 2010a). Iran GDP increased with an average rate over 5.5% from 1998 to 2008. The growth of GDP by type of activities is shown in figure 1.1. As can be seen in this figure the services section that includes the transportation increased like many developing countries.

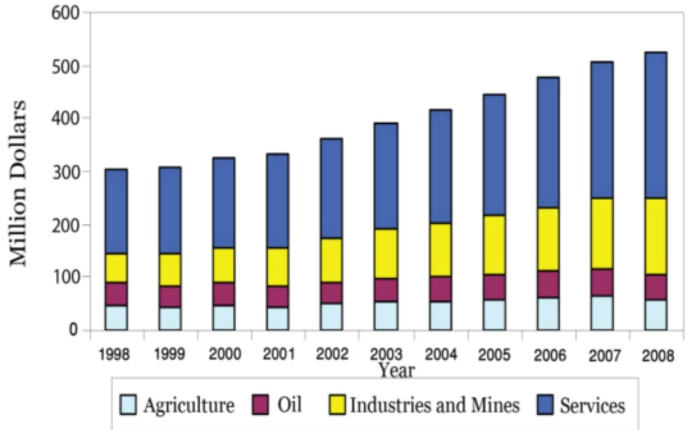


Fig. 1.1. The GDP due to the types of activities in Iran (IIES 2010)

It is evaluated that the total primary energy supply increases with 59.9 percent from 2001 and reaches to 1493.21 million barrels of oil equivalent (Mboe) in 2008. This increase of the primary energy supply is considered high for developing countries. According to the figure 1.2, crude oil is the biggest type of fuel that is consuming in Iran.

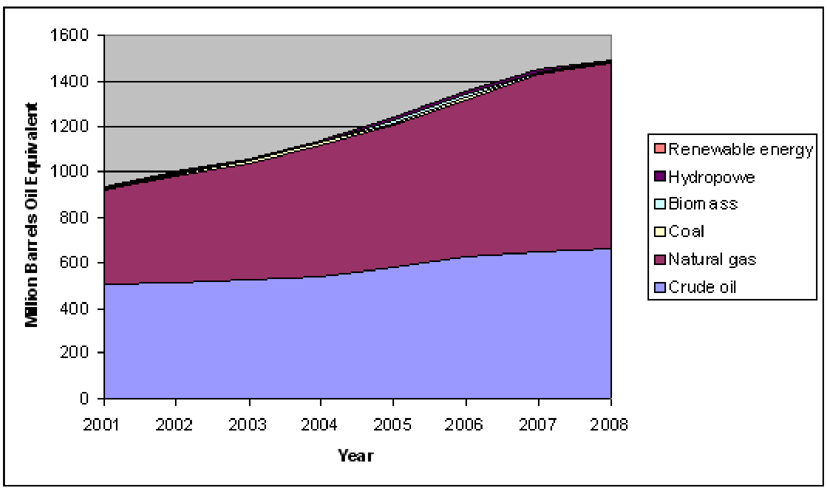


Fig. 1.2. The primary energy supply based on fuel types in Iran (Power 2010)

According to the industrialization the final energy consumption increased in the past decade in Iran. With an annual growth rate of 6.4% the final energy consumption has risen and reaches 1187.4 Mboe in 2008 (IIES 2010). The final energy consumption in the various sectors in Iran is shown in figure 1.4.

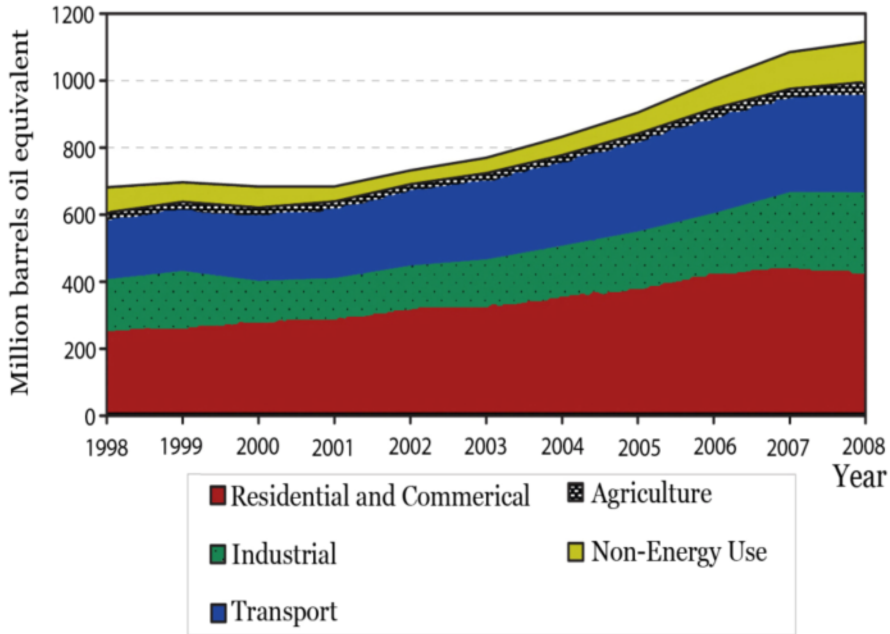


Fig. 1.3.Final energy consumption by sectors from 1998 to 2008 (Power 2010)

As can be seen in figure 1.4 the transportation sector is the second largest energy consumption in Iran. The crude oil and natural gas are the most important energy supplier in Iran (SUNA 2010).

The burning fossil fuels specially by the transportation sector causes greenhouse gas emissions that have negative effects on the environment (Dincer 2000). The dependency of Iran energy scenario to fossil fuels, consider to this fact that this sources will be depleted one day, will cause an adverse effect on the economy of Iran. Therefore, actions toward implementing energy policies such as fuel economy standards and labels should be put as a priority by the government.

Along with rapid economic development in Iran, Iran's transportation sector is also growing. In 2008, the transportation sector in Iran consumed about 25 percent of the entire energy demand (IIES 2010). Figure 1.5 presents the final energy use by sector. This energy is used by different types of transport such as motor vehicles, motorcycles, buses, freight vehicles, trains, planes, and other types of transportation systems to provide services to the community.

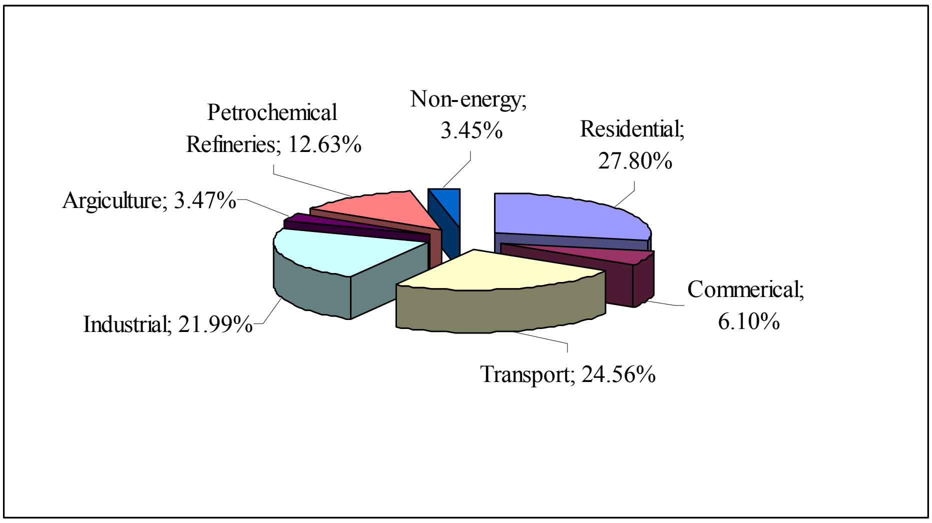


Fig. 1.4.Final energy use by sector in 2008 (IIES 2010)

The final consumption of oil products in 2007 is shown in Figure 1.5 and the Figure 1.6 shows the percentage of energy used in the transport sector due to the fuel types.

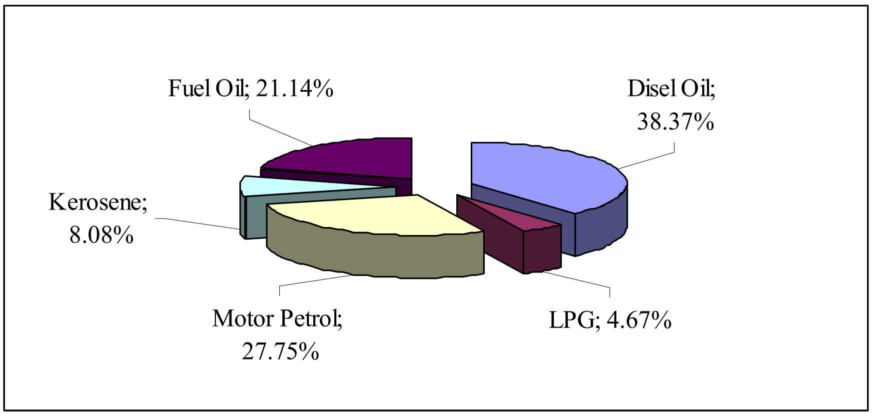


Fig. 1.5.Final consumption for petroleum product in 2008 of 88,227 million liters (Power 2010)

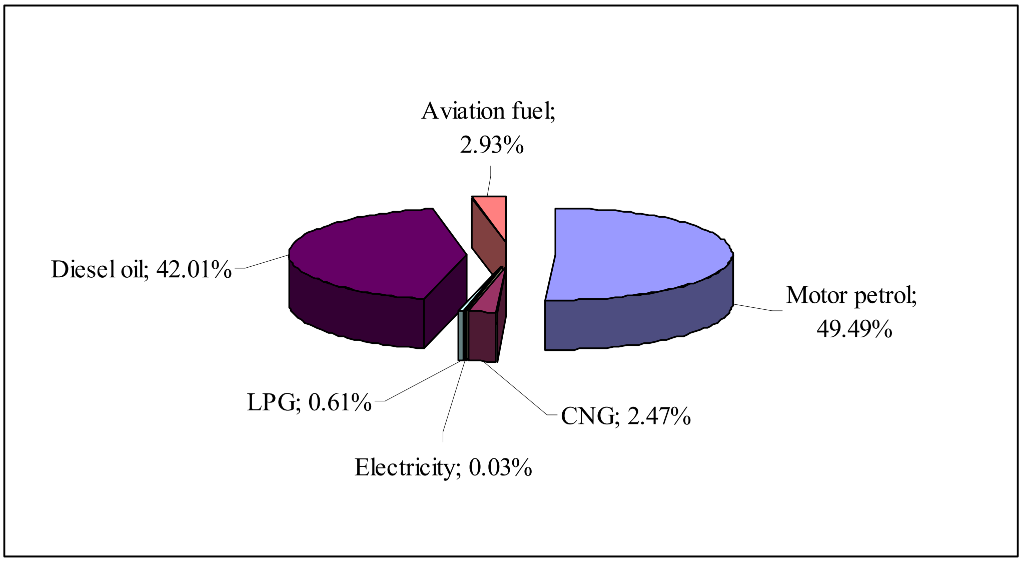


Fig. 1.6.Percentage of transportation sector energy use based on fuel types in 2008 of 258.47 Mboe (Parsafar, Mirzaee et al. 2010)

The transportation sector not only preserves the dwindling energy reserves, but also will lead to reduce air pollution, particularly CO_2 emissions. The CO_2 emissions produced in different parts is shown in figure 1.8. As shown in the Figure 1.8, the transportation sector is one of the largest participants in CO_2 emissions that it contributes about 24 percent in 2007 (Power 2010).

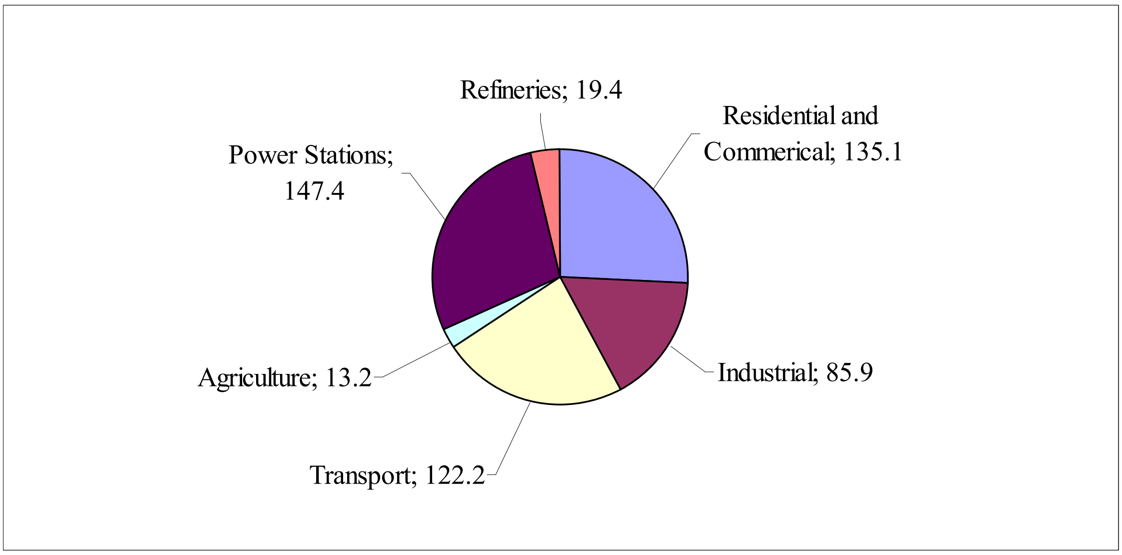


Fig.1.7.The amount of CO_2 emission in different sector of Iran 2008

Using energy efficiently in order to keep the energy reserve available and care about the environment are two important factors involved in the current global market.

Therefore, many countries are implementing a policy for energy efficiency and transportation systems.

1.1.2 Iran energy policies

In order to reduce the growth in consumption of oil products in Iran, the optimize fuel consumption organization defined the five as principles the main activities in the transportation sector. These principles are:

1. Improved methods of transportation
2. Technology for light duty vehicles
3. Technology for heavy duty vehicles
4. Development of improved fuel
5. Development of standards and fuel consumption

In this view, the main goal is reducing the consumption of petroleum products and reduction the amount of produced pollutants by used fuel in transportation is considered as a secondary target (IIES 2010).

National policies to reduce fuel consumption has been scheduled by both policies based price and non-price. The works which have been done in the based price policy in order to save energy are:

- To quota the gasoline and engine oil through smart card, controlling and reducing the consumption of these products
- To using natural gas (CNG) as an alternative fuel in the transportation sector
- To develop of public transportation system and the metro networks
- To develop and improve the facilities of technical examination centers, and testing all vehicles compulsory in order to reduce the fuel consumption, environmental protection and traffic safety

- To eliminate the old and retired cars in the private and public transportation systems
- To developed and improve the traffic management in the country by building highways
- To train the methods of energy management for companies and factories

In based price policy of the country the economic development plan and the stepped pricing of gas program are implemented to remove energy subsidies; in order to scrounge and reduce energy consumption.

Transportation sector in Iran is largely dependent on the road vehicles. Motor vehicles ownerships have been promoted so that vehicle manufacturing industry is an important factor for economic development in Iran. Based on the type of fuel, motor petrol and diesel oil contribute 49.49 percent and 42.01 percent of total fuel consumption in the transportation sector, respectively. Therefore, as a starting point it is also necessary to concentrate to reduce energy consumption in transportation sector.

1.2 Objectives of research

According to the energy consumption and the Iran policies, in this research is tried to develop the fuel economy standards and labels for light duty vehicles in Iran that is the major objective of this study. This program can help the country to reduce energy consumption, to gain economic benefits and environmental positive effect. Development and the implementation of fuel economy standards and labels reduce fuel consumption, especially in the transportation sector in a country. Decreasing the fuel consumption causes to reduce greenhouse gas emissions which have a negative impact on the environment. In this research, following objects are considered to overcome due to the main objective.

- To select a suitable motor vehicle fuel consumption test procedure in order to use in for light duty vehicles in Iran
- To propose the fuel economy standards and labeling program for light duty vehicles in Iran
- To conduct the cost efficiency analysis to estimate potential fuel economy improvement and cost estimates on future fuel consumption
- To predict the market transformation when the fuel economy standards and labels program is implemented
- To predict the potential financial savings and environmental impact of fuel economy standards and labels program for light duty vehicles in Iran

1.3 Contributions of the research and Limitation

This study is essential that it will cause considerable contributions in energy demand in the future. This study includes the selection of appropriate test procedure, fuel economy standards and labels for light duty vehicles in Iran. However, the main contribution of this study is to develop a comprehensive strategy on the implementation of fuel economy standards and labels especially for light duty vehicles which are locally produced. The instructions include determining the specific steps of procedures, and evaluating the impact of fuel economy standards and labeling program for light duty vehicles.

Some input data must be known in order to develop the fuel economy standards and labels program satisfactorily. Like many other developing countries this information is not collected professionally in Iran. For the study, the data of the characteristics of the motor vehicles and their fuel consumption in the transportation sector is essential. For this research the information of models which are locally produced are collected.

1.4 Organization of the research project

The five chapters of this research project contains following index, in summary:

Chapter 1 includes the energy scenario of Iran and background of the energy policies, aims and limitations of this research. The current transportation system and energy situation in Iran is introduced in this chapter.

Chapter 2 reviews related studies on the fuel economy standards and labeled. A comprehensive review is done to examine the relation of literatures reviewed and this study**.** Some of the resources are journal articles, research reports, conference papers, published books and internet database.

Chapter 3 contains research methodology to develop test procedure, execute the fuel economy standards and labels, to present the methods for analyzing economic/engineering approach in order to calculate the changes in the market. Also the method to calculate the impact on energy, economy and environment with respect to fuel economy standards and labels are represented.

Chapter 4 includes the discussion of methodology for case of light duty vehicle in Iran and also the results of research based on calculating due to the methodology. The required data such as the motor vehicle model, engine size and fuel economy rating are collected. The information are collected from published books and articles and also from the fuel consumption optimizing organization of Iran and Iran Ministry of Energy and their libraries databases. The achieved result such as fuel economy standards and label, market transformation and the impact of the program in the case of Iran are presented.

Chapter 5 has been shared into two parts, the present research results and recommendations. In this section, the obtained results of study are summarized and recommendations are suggested to ensure a successful implementation of fuel economy standards and labels plan.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The transportation sector has the second largest contribution in oil products consumption in Iran. The transportation sector contributes around 269.8 million barrels oil equivalent (Mboe) of oil production in 2008. The production of light and heavy-duty vehicle grew at an average rate over 12.2% and 17.7% in Iran from 2001 to 2009, respectively (Power 2010). The large number of the vehicle has been one of the most effective issues in the increasing of petrol and gasoline fuel consumption during recent years.

Iranian government has implemented various policies and programs such as applying quote on petrol consumption and changing the policies of subsidizing of petrol for optimization of fuel consumption in the transportation sector during last 5 years ago. Therefore, it is really important to make the consumer aware of fuel economy and influence their purchasing decision.

There are some strategies to guide the society in an effort to promote the motor vehicles which are more efficient in fuel. One of the most effective strategies is to implement a fuel economy standard (Clerides and Zachariadis 2008). Only the motor vehicles which has fuel economy standards can be sold legally and the motor vehicles without suitable performance can not be entered the market. In fact, fuel economy standard identifies a bottom line of achievement and it performs as a base line for the vehicle manufacturer.

In order to set up standards and labels program for motor vehicles in Iran, it is necessary to have an overview of other related studies regarding fuel economy standards and labels in the other countries. The energy policies, manufacturing structure, culture and climate are some issues which do not let us to use the successful standards and labels of the other countries, in Iran directly (Egan 1998). Despite this, it is possible to use these programs in some approaches and modify them when it is required base on conditions in Iran.

2.2. Test procedure

Generally, a driving cycle is a static vehicle velocity that is developed to show the local driving patterns, which constitutes the speed of vehicle against the time. It is used exclusively in determining vehicle's emissions, computing fuel consumption, and evaluating traffic effect (Wang, Huo et al. 2008; MetricMind 2011). Moreover, all the tests have been simulated a range of driving conditions, at highway speeds that these speeds are more common in urban driving. Particularly most of the tests depreciate the real life fuel consumption of vehicles (UNEP 2011). Fuel economy has been testing for new vehicles contrast for different areas.

The importance and priority of the test cycle driving can listed as below:

- It uses as a standardized measurement indicator for fuel economy and emissions
- By using driving cycle and test procedure the standards can be set
- It shows the average or typical driving
- Emissions standards are substantially dependent on the cycle and testing procedure

Due to the changing policies and laws for driving, the test procedure could change over the times.

As long as countries work to establish fuel economy standards, the details of every test procedure will come under more surveillance manner. Manufacturers are more looking for a way to make the testing requirements cheaper and simple. Some manufacturers consider complex or unique test procedures in order to achieve best fuel economy rating. Manufacturers willing to ensure that their vehicles appear with fuel efficient as best as possible, while consumers need is the test procedures in order to reflect the best result of real driving (Meier and Hill 1997).

In order to express the driving conditions, some driving cycles have been developed in various countries. The most important test cycles for emissions and fuel economy are as below (Montazeri-Gh and Naghizadeh 2003).

International driving test cycles for fuel economy and emissions:

- US driving test Cycle
- European driving test Cycle
- Japanese driving test Cycle
- Australian driving test Cycle

2.2.1 United State Test Cycle

During last three decades, the different types of driving cycles have been developed in various regions of USA. The standards cycles for U.S driving are (Mirzaee, Parsafare et al. 2008):

- FTP72[1],
- FTP75[2],
- HWFET[3],
- IM240[4],
- (UC) LA92[5],
- NYCC[6]
- SFTP US 06[7]

[1] Federal Test Procedure 1972
[2] Federal Test Procedure 1975
[3] High Way Fuel Economy
[4] Impaction and Maintenance
[5] California Unified Cycle
[6] New York City Cycle
[7] Supplemental Federal Test Procedure United State

The CAFÉ (U.S.-based Corporate Average Fuel Economy) driving cycle is used to express the driving condition in United State. This standard driving cycle indicates both condition of urban and suburban driving. The CAFÉ includes 45% of highway driving and 55% of city driving (Mirzaee, Parsafare et al. 2008). According to the condition of city driving, test cycle initiated with a cold engine. The length of the cycle is 21 minutes that it composes of 23 steps over this period. The maximum speed of city driving for test cycle has considered 90 km/h. Furthermore the average speed of cycle for city driving is 32 km/h. The drive cycle method has been modifying by EPA (the U.S. Environmental Protection Agency) from 2008 (Mirzaee, Parsafare et al. 2008)

The highway test cycle driving has processed due to warmed up engine without any cut off or stop. The traveled distance in this part of the cycle is 16 km. The maximum and average velocity of this cycle is 97 km/h or 77 km/h respectively. (Mirzaee, Parsafare et al. 2008)

From 2008, the drive cycle method has been modifying by EPA (the U.S. Environmental Protection Agency). The modified EPA test cycle is illustrated in figure 2.1. There are also some other important driving test cycle in United State such as; FTP-75, SC03, US06, LA92 and IM-240 (Montazeri-Gh and Naghizadeh 2003)

The FTP-75 test cycle is a transient one and generally, it is used in order to certify the emission of light duty vehicles.

The LA92 is known as dynamometer driving test. Genuinely it is planned for light-duty vehicles that developed by the California Air Resources Board. The LA92 driving cycle is more aggressive and inspiring than the federal FTP-75 which characterizing because of higher speed, higher acceleration and speeding up, fewer stops and ceases per mile, and less idle time without wasting time.

One of the test cycles that is using for chassis dynamometer, is IM-240. This test cycle is useful for evaluating the emission of light duty vehicles.

The SC03 test cycle can be considered as Supplemental Federal Test Procedure (SFTP). This test cycle includes: emission testing, engine load and using air conditioning over the FTP-75 test cycle.

The US06 cycle is Supplemental and derivative Federal Test Procedure. The reason for developing this cycle was to address shortcomings with the FTP-75 test cycle. The US06 cycle is aggressive. In 2011 the new USO6 and SC03 test cycles are used to determine fuel economy.

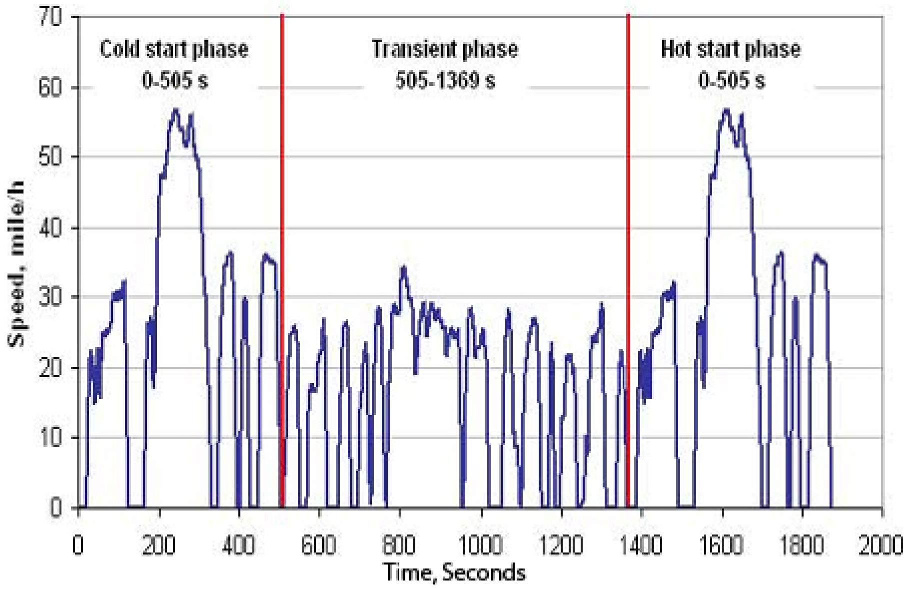


Fig.2.1.EPA City Cycle Test – For City Fuel Economy and Emissions

2.2.2 European Test Cycle

The standardized test cycles are official process for evaluating emissions and fuel consumption. Since 1970, they are so effective for standardization and they have frequently updated in Europe. The European cycles are such as ECE-15, EUDC, EUDCL, HYZEM and NEDC (Montazeri-Gh and Naghizadeh 2003).

The main usage of The ECE-15 (Emission Certification of light duty vehicles in Europe) cycle is for urban driving test. This cycle also known as Urban Driving Cycle (UDC). However, this cycle has low velocity (maximum 50km/h), low engine loud and low-temperature gas output. The ECE-15 cycle is known as modal cycle, which has some parts in cycle with constant velocity. Besides the total traveled distance in this cycle is 4.052km with duration of 780sec. Meanwhile the average speed of the cycle is equal to 18.7km/h.

The EUDC (Extra Urban Diving Cycle) is still a modal cycle. The main aim of planning this cycle is for the suburban driving. In comparison with ECE-15, the velocity and the acceleration of this cycle are more. At the end of EUDC cycle, the vehicles accelerate up to velocity of the vehicle in the highway (maximum 120km/h). This cycle is shown in figure 2.2.

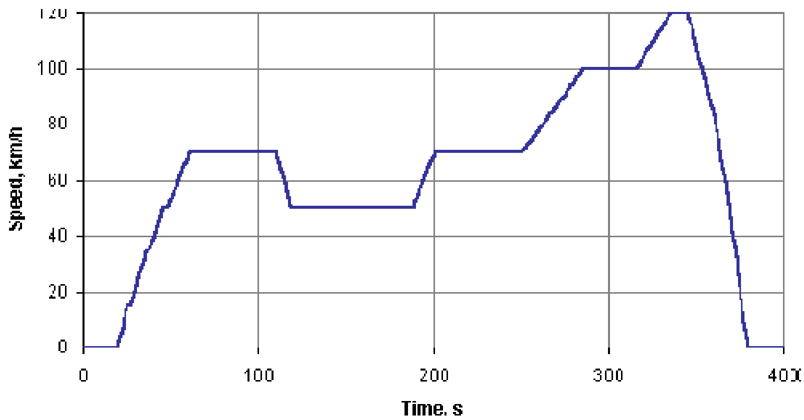


Fig.2.2. Extra Urban Diving Cycle

The total traveled distance and duration of EUDC cycle are 6.955km and 400sec. In spite of the average speed in this cycle is 62.6km/h.

For vehicles with low power, The EUDCL (Extra Urban Driving Cycle Low power) cycle is known as an extra urban cycle. This cycle is quite similar to EUDC, but the maximum speed in EUDCL is equal to 90km/h.

In HYZEM cycle, parts with constant velocity are much less than modal cycles. This cycle has a good advantage that it has been taken from the real patterns of driving in Europe and has much better representation for driving conditions rather than the mentioned cycles. The average velocity and maximum acceleration in this cycle is 68.36 km/h and 3.1 m/s^2 (Montazeri-Gh and Naghizadeh 2003).

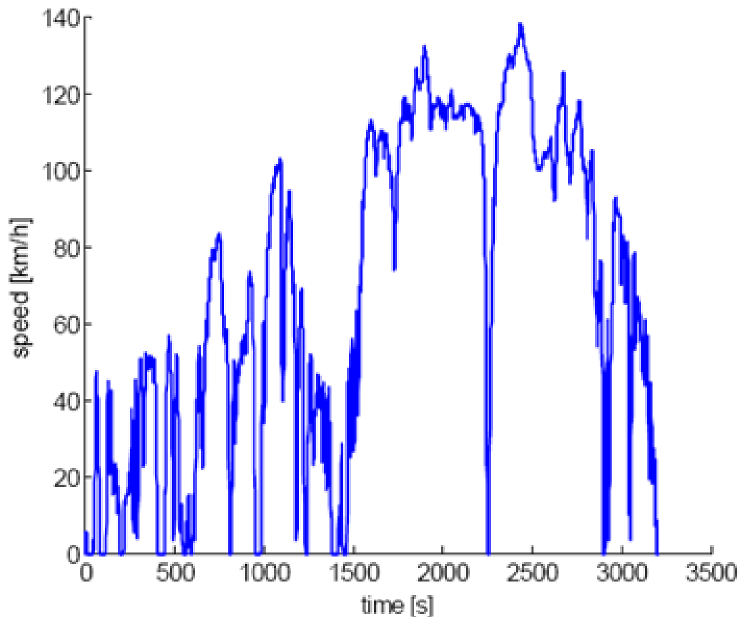


Fig.2.3. The HYZEM driving cycle

The ECE+EUDC driving test cycle is analyzed based on a chassis dynamometer. This cycle is suitable used for certifying the emission of light duty vehicles. This test cycle is also called the MVEG-A cycle. Actually this cycle is composed of four segments of ECE-15 and one segment of Extra Urban Driving Cycle (EUDC) at the end EUDC:

The ECE+EUDC test cycle is recognized as New European Driving Cycle (NEDC). Emission sampling procedure starts simultaneously with the time of starting the engine after converted to cold start procedure by eliminating idling procedure. This cycle is an illustration of typical city driving conditions in Europe.

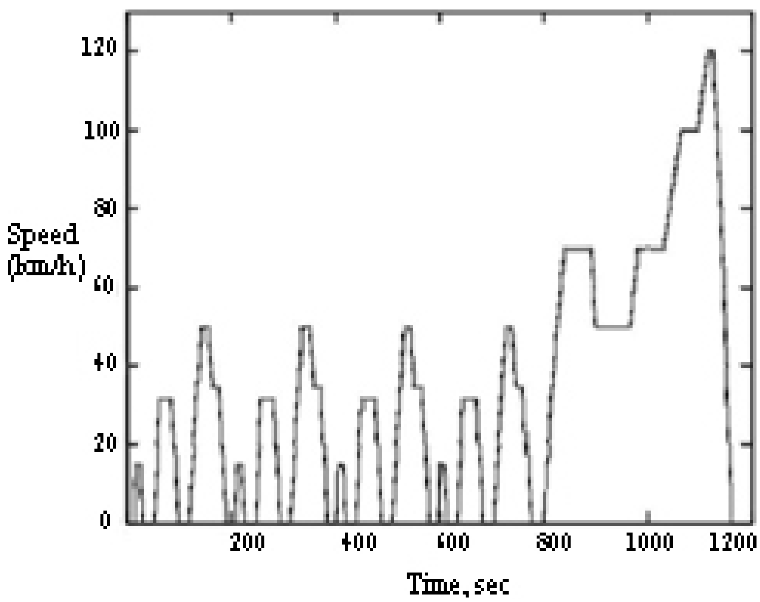


Fig.2.4. The New European Driving Cycle (NEDC)

2.2.3 Japanese Test Cycle

The test cycle that known as JC08 is introduced by Japanese emission regulation in 2005. This cycle is a new of driving test cycle for light duty vehicles which is based on a chassis dynamometer (< 3500 kg GVW). The JC08 shows driving in jammed city traffic (idling duration and frequently changing acceleration and deceleration). This cycle mostly used for determining the fuel economy and measuring the emission. The cycle for measuring runs twice with a warm start and with a cold start under the JC08 test cycle. This test cycle was fully phased in October 2011.

Before this the Japanese used the driving cycle with following details (UNEP 2011):

- %12 :2005.10of 11 mode cold start + 88% of 10-15 mode hot start
- %25 :2008.10of JC08 mode cold start + 75% of 10-15 mode hot start
- %25 :2011.10of JC08 cold start + 75% of JC08 hot start

The reason of designing the JC08 test is to evaluate the progress toward obtaining the revised 2015 targets. The same as old 10-15 cycle, the JC08 test cycle has some advantages such as higher average and maximum velocities and needs more aggressive acceleration maximum speeds and requires more aggressive acceleration (An, Gordon et al. 2007). Demonstration of the old and new test cycle of Japan is shown in figure 2.5.

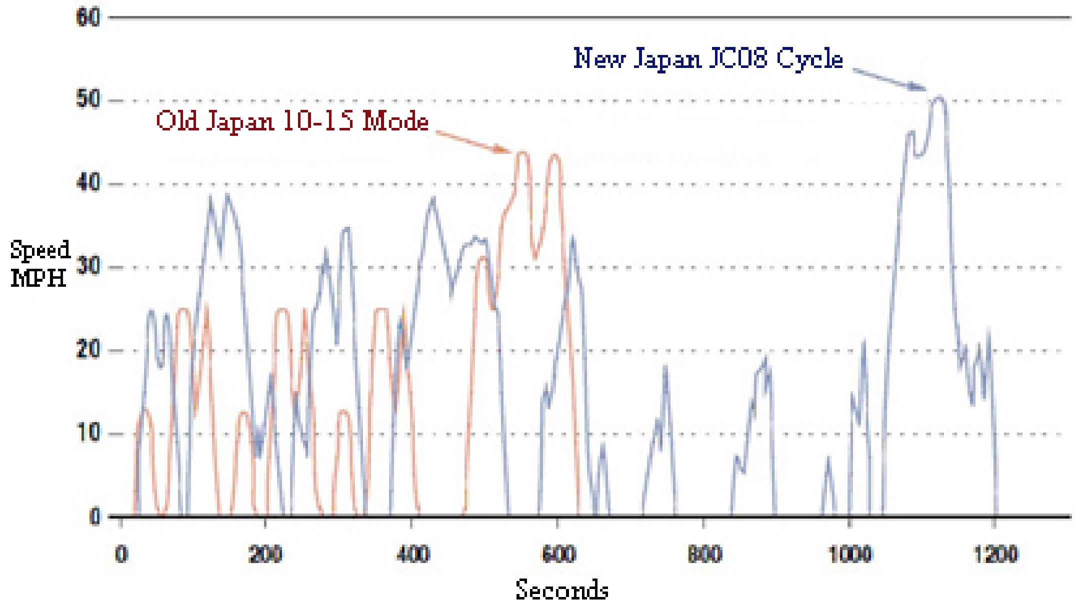


Fig.2.5. The Japanese Driving Cycle

The more accurate JC08 test cycle fulfilled to more increase the severity of the 2015 standards due to the difference which can be seen in figure 2.6 (An, Gordon et al. 2007).

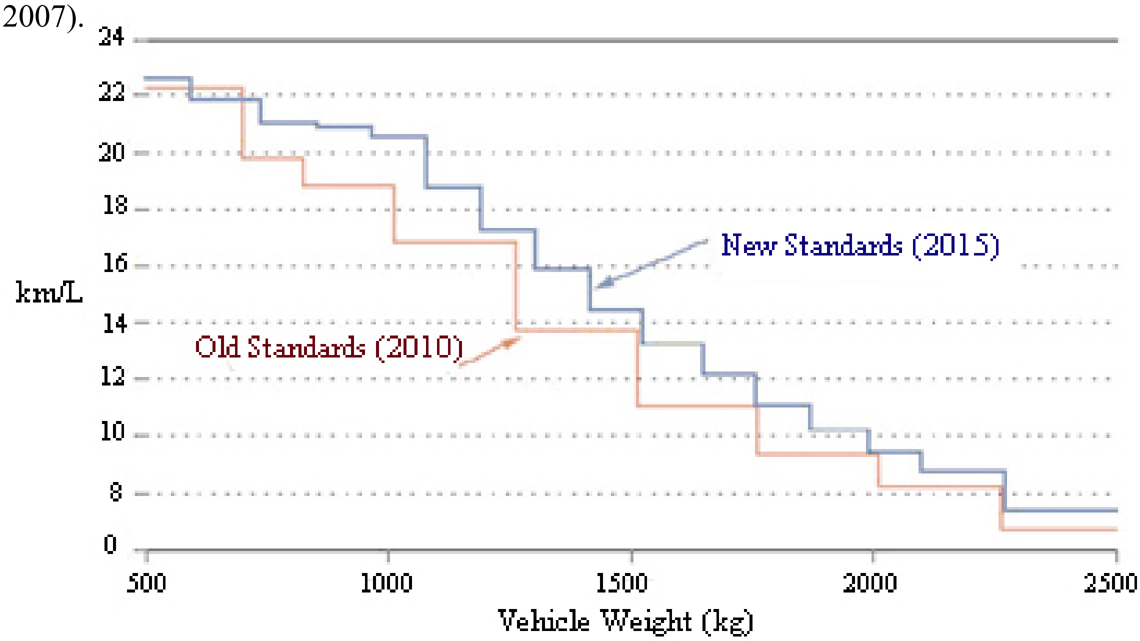


Fig.2.6. The Japanese standards

2.2.4 Australian Test Cycle

The test of standardization for the present energy label (fuel consumption) is determined in *ADR 81/01 Fuel Consumption Labeling for Light Vehicles* in Australia (UNEP 2011). This dynamometer test driving is leading to measure the fuel consumption and carbon dioxide emission for automobiles and vehicles under laboratory situation. The comparison of main test procedures is summarized in Table 2.1 (UNEP 2011).

Table 2.1.Comparison of the test procedures used globally

Cycle	Duration(s)	Average speed (Mph)	Average speed (km/h)	Max speed (Mph)	Max speed (km/h)	Average speed (Mph/s)	Max Acceleration (kmh/s)
NEDC	1181	20.9	33.6	74.6	120	2.4	3.9
JC08	1204	15.2	24.5	50.7	81.6	3.8	6.1
CAFÉ	-	32.4	-	59.9	-	3.3	5.3
EPA City	1375	19.5	31.7	56.7	91.3	3.3	5.3
EPA Highway	766	48.2	77.4	59.9	96.4	3.3	5.3
US06	596	48.4	-	80.3	-	-	-
SC03	596	21.6	-	54.8	-	-	-

The International Council on Clean Transportation which is known as 'ICCT' have compared different test cycles such as NEDC, CAFE, and JC08 test to measure the fuel consumption. A methodology to normalize cycles is developed and a test cycle conversion instrument is available online in ICCT website which is accessible worldwide. The result of rating on fuel economy for vehicles under the different test cycle is reported in table 2.2 (ICCT 2011).

Table 2.2.Simulation Results for Gasoline Vehicle Fuel Economy Rating under Test cycle

			Test cycle FE (MPG)			Test Cycle Multiplier		
Type	Make	Model	NEDC	CAFÉ	JC08	NEDC,JC08	CAFÉ,JC08	CAFÉ, NEDC
Small Car	Ford	Focus	26	29.8	22.9	1.14	1.3	1.15
	Toyota	Corolla	32.4	34.8	27.6	1.17	1.26	1.08
	Toyota	Yaris	40.6	42.2	36.1	1.12	1.17	1.04
	Honda	Fit	36	40.1	31.8	1.13	1.26	1.11
	Hyundai	Accent	35.1	36	32.1	1.09	1.21	1.11
	Kia	Pio	35.4	39.1	32.2	1.1	1.21	1.1
	Deawoo	Aveo	31.2	35.5	26.1	1.19	1.36	1.14
Large Car	Toyota	Camry	24.7	26.6	21.5	1.15	1.24	1.08
Marian	Dodge	Grand Gravan	20.5	23.9	17.2	1.19	1.39	1.17
SUV	Ford	Explorer	17.6	20.2	14.6	1.2	1.38	1.15
Pickup	Chevrolet	Silverado	15.9	18.8	13.5	1.18	1.39	1.18
Simple Average						1.15	1.29	1.12

There are a large set of test cycles for different regions around the globe. The Swiss Handbook cycles are collected the Swiss driving style (De Haan and Keller 2001). There are Neapolitan driving patterns (Rapone, Della Ragione et al. 1995), and also a lot of other cycles which are using to show the real-world driving conditions in various European countries and characteristics are given in reference (André, Rapone et al. 2006a; André, Joumard et al. 2006b).

2.2. Fuel economy standards

Regulation and setting the standards can be considered as two powerful instruments to reduce emissions and clean up transport. Regulations can be based on various metrics and measurements such as fuel economy, CO_2 emissions and greenhouse gas (GHG) emissions (ICCT 2011). Fuel economy and CO_2 emission standards are a valuable method for overcoming the natural conflict to invest in fuel economy which results from the inherent effects of changing in oil price. More than 75% of the world light duty market has fuel consumption, fuel economy, or carbon dioxide (CO_2) standards.

There are different kinds of approach to standard setting for countries, and those are targeting rates of fuel economy improvement which may different from each other, but all of them have the same goal and target to promote more efficient cars .

The fuel economy is related directly to cost of fuel because light-duty vehicles account in case of the large percentage of oil consumption. Therefore, Fuel economy continues can be considered a main issue of public and policy interest. The fuel economy is straightly related to emissions of GHG such as CO_2 as the light duty vehicles contribute emissions. Moreover, implementing of the fuel economy standards are caused to improve vehicles' technologies. Table 2.3 is shown the major characteristics of light duty vehicles.

Table 2.3.Characteristics of Light-duty three model year

	1975	1987	2005
Adjusted Fuel Economy	13.1	22.1	21
Weight (lb)	4060	3220	4089
Horsepower	137	118	212
0 to 60 time (s)	14.1	13.1	9.9
Recent Truck	19%	28%	50%

Most of the countries have implemented the fuel economy standards due to their specific conditions and situations. The fuel economy standards in the process and under development for some countries around the world are demonstrated as follow in summary.

Table 2.4.Fuel economy and GHG emission standards around the world

Country/Region	Standards	Measure	Structure	Targeted Fleet	Test Cycle	Implementation
Japan	Fuel	km/l	Weight-based	New	JC08	Mandatory
European Union*	CO2	g/km	Single Standard	New	NEDC	Voluntary
China	Fuel	l/100km	Weight-based	New	NEDC	Mandatory
Canada*	GHG	5.3 Mt reduction	Vehicle class-based	In use and New	US CAFÉ	Voluntary
California	GHG	g/mile	Vehicle class-based	New	US CAFÉ	Mandatory
United States	Fuel	mpg	Single Standard	New	US CAFÉ	Mandatory
Australia	Fuel	1/100km	Single Standard	New	NEDC	Voluntary
South Korea	Fuel	km/l	Engine size-based	New	US EPA	Mandatory
Taiwan, China	Fuel	km/l	Engine size-based	New	US CAFÉ	Mandatory

** are shifting to mandatory*

Some countries (like Germany, Japan, Switzerland and Korea) have established target levels voluntary fuel economy standards. Usually these voluntary agreements are between the government and manufacturers. They can be determined based on a statistical method without involving wide spread in public. In some cases, (e.g., Switzerland), companies are given an ample time in order to achieve the voluntary point in standard and on the other hand, if they do not comply, the regulatory agency can take alternative mandatory standards

2.2.1 USA Fuel Economy Policy

The first comprehensive fuel economy standard for products was implemented in the State of California in America 1977. These standards were effectiveness and followed by additional other states also to reach better optimization point. Eventually, this heterogeneous mix of standards in various states motivated manufacturers to develop the national consensus standards with efficiency advocates (Turiel, Chan et al.

1997). The fuel economy standards are mostly in the form of minimum energy performance standards (MEPS) in the United States, they have established minimum efficiencies, in the other words, maximum energy consumption. Therefore, after a certain date, manufacturers must achieve it at all new automobiles that have produced.

2.2.2 The European Union Fuel Economy Policy

The European Union has signed the voluntary agreements "ACEA Agreement" to reduce CO_2 tailpipe emissions about a decade ago (An and Sauer 2004), the agreement was established wide target of 140 grams CO_2 per kilometer in industries (6 l/100km or 39 mpg).(UNEP 2011)

The Council of Environment Ministers have determined formally a resolution since June 2007 to approve the shift to compulsory standards and an integrated approach through technical improvements and the complementary measures to decline emissions and achieving 140 g/km.(Commission 2007; UNEP 2011) The national average of fuel economy decreased around 2% due to implementing multiple economy policies in the European Union during 2005 to 2008 (IEA 2010). The European Parliament and the Council approved regulation settings on April 23, 2009. Therefore, they identified 130 g/km for the average emissions of new cars that are producing to be completed by 2015. Moreover, they aimed to reduce emission to 95 g/km which has been established for future targets in 2020 (MEF 2006).

2.2.3 Russia Fuel Economy Policy

Russia has contributed to a rapid increase in motorization which has been grown over the last decade. Private vehicle ownership had grown by 84% during 1995-2006 (UNEP 2011). Passenger car sales rose by 30% to 1.78 million units in 2010. The Russian transportation segment was responsible for 25% of final energy consumption

(94.4 mtoe) in 2005. In order to reduce emission and fuel consumption in Russia following policies will be applied (Segizova and Jochem 2011):

- Research on fuel economy standards.
- Development of a plan for increasing awareness about fuel economy in the society.
- Do pilot projects for raising fuel economy

Russia can reduce the energy consumption in the transport sector by 41% compared to levels which were existed in 2005 due to the report by the World Bank Group. The figure 2.7 shows the potential fuel economy improvement in the transport sector in Russia.

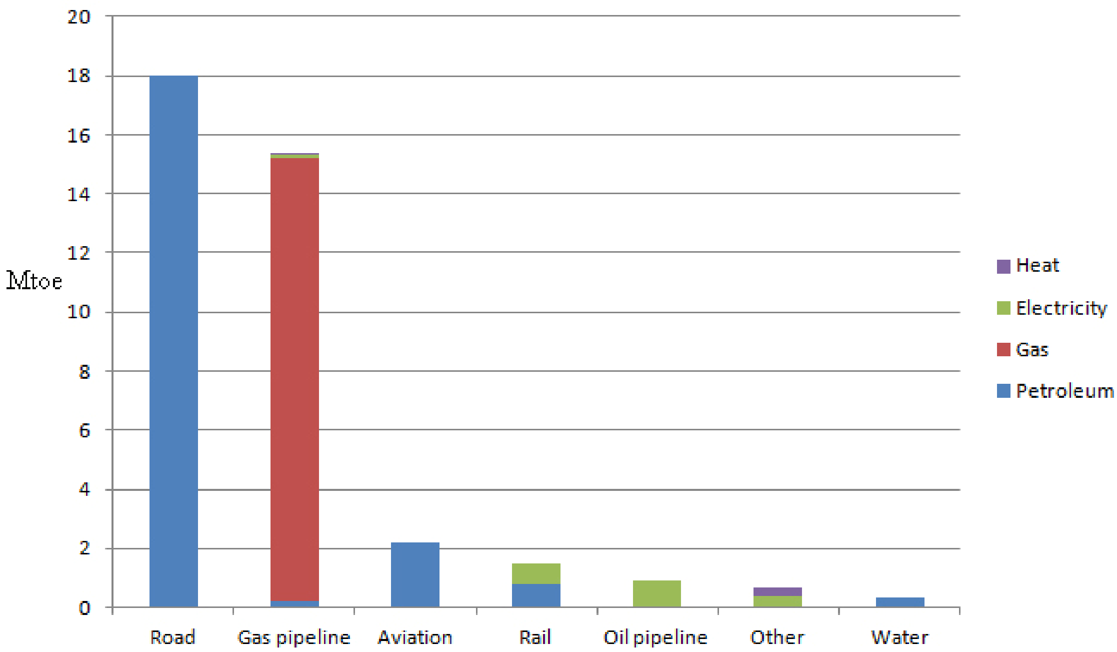


Fig.2.7.potential fuel economy improvement in the transport sector in Russia (*mtoe*) (UNEP 2011)

2.2.4 Turkey Fuel Economy Policy

Around 90% of demand is covered with oil import in Turkey (Ernst and Young 2011). Transportation sector has the main role that consumes the huge amounts of the oil and petroleum. Hence, the national energy efficiency schedule earned a main promote to adopt a regulation on increasing the fuel consumption in transportation due to the Energy Efficiency Law in 2007. Turkey is a candidate country to the EU, therefore it will be responsible for the ultimate agreement of EC regulation 443/2009, Therefore must try to increase fuel economy rating and decrease the fossil fuel (UNEP 2011). The table 2.5 demonstrates the Turkish Legislation for fuel economy improvement.

Table 2.5.Turkish Legislation for fuel economy improvement

Legislation Name	Type	Target	Year
EIE Information activities	Education and Outreach	Framework, Multi-sectoral policy	Various
Support Scheme foe Energy Efficiency	Subsidies, Voluntary agreement	Industry	2008
Energy Efficiency Law No. 5627	R&D, Subsidies, Regulatory, Voluntary agreement	Framework, Multi-sectoral policy	2007
Monitoring Energy Efficiency in Sectors	Regulatory	Industry	2007
Energy Management	Regulatory, Education	Industry	2006

2.2.5 Canadian Fuel Economy Policy

Car manufacturer in Canada and United States have the same fuel economy standards, but there are no penalties or fines in Canada and standards are voluntary (ICCT 2011a). In the world the fee bate program has been established only in Canada for vehicles based on fuel consumption (CRA 2011). According to Memorandum of Understanding (MOU) between the government and the car industry the Canadian fuel economy standards are established. Actually the MOU was an addition to the established Corporate Average Fuel Calculation (CAFC) standard moreover it was based on vehicle emissions reductions (Plotkin, Greene et al. 2003). Canada released a draft regulation in April 2010, that uses to limit gas emissions from light duty vehicles from models between the years 2011 to 2016 (NEB 2008). The prediction of Canadian government is that the average gas emission performance of the 2016 Canadian light duty vehicles would match the average level of 153 gr carbon dioxide per km (169 grCO2/km under NEDC cycle).

2.2.6 The Chinese Fuel Economy Policy

Since September 2004 in order to develop vehicle technologies and decrease the fuel-consumption rates of individual vehicles China has implemented new strategies (Oliver, Gallagher et al. 2009; Huo, He et al. 2011a). In comparison to most other developed or developing countries, China has more small cars overall than others so that it more focuses on improving the fuel economy of light duty vehicles. Table 2.6 present the projected market share in china.

Table 2.6.Present the projected market share in china

Vehicle Type	Year					
	1990	2000	2005	2010	2030	2050
Trucks	78.7	36.4	31.4	26.4	19.5	19
HDT	3.9	4	4.5	4.6	4.6	5.3
MDT	37.6	7.5	4.5	3.9	3.1	3.2
LDT	32	18.6	17.7	14.9	10.9	10.6
MiniT	5.3	6.4	4.7	3.2	1	0
Buses	9.9	34	21.6	13	4	1
HDB	1.1	0.4	0.5	0.7	1.5	0.8
MDB	0.5	1.7	0.9	0.5	0.3	0.1
LDB	8	12	8.6	5.1	1.1	0.1
MiniB	0.3	19.9	11.7	6.7	1.2	0.1
Cars	11.4	29.6	47	60.6	76.5	80
Small Car	9.7	22.2	28.2	37.3	50.5	56
Large Car	1.7	7.4	18.8	23.3	26	24

In the beginning of 2005, China started to implement vehicles fuel economy standards in 2 phases in order to decrease the energy consumption by these cars. From 2002 to 2006 the first Phase has implemented and fuel consumption limits due to sales-weighted therefore average fuel consumption decrease of around 11%. Then second Phase implemented in 2009 (Wagner, An et al. 2009). Also, in order to control the oil demand of passenger cars China has used many policy measures lately. For an instance in 2010, China began to report the fuel economy rating of light duty vehicles through labels for new vehicles (Huo, Yao et al. 2011).

2.2.7 India Fuel Economy Policy

Today the number of vehicles is roughly about 40 million. At the same time in India the number of vehicles is growing at the rate of over 5% per year. India has the high proportion of two wheelers (76%). Likewise India is the fifth largest greenhouse gas (GHG) emitter (about 5% of global emissions). Between 1990 and 2005 the emissions increased 65% and another 70% are predicted to grow by 2020 (Govern.India 2010). India's first National Action Plan on Climate Change (NAPCC) is expressed in 2008 that is outlining currently and future policies.

2.2.8 Australia Fuel Economy Policy

For the 2011 it has reported that the light duty vehicles are 76.2% of all vehicles in Australia (ABS 2011). The Federal Chamber for Automotive Industries (FCAI) focuses on the light duty vehicles. The FCAI established a voluntary target in 2005 in order to reduce the National Average Carbon Emissions (NACE) to 222 grams of CO_2/km for light duty vehicles under the NEDC driving test cycle by 2010. In Australia, the agreement makes with industry to reduce swift average fuel consumption for motor vehicles to 15 percent by 2010 (over the baseline 2002). This agreement is voluntary. Moreover this agreement has no particular enforcement mechanisms or fines (An, Gordon et al. 2007).

2.2.9 Japan Fuel Economy Policy

According to Japan Policy, Standards are identified based on the weight class. It introduced in 1999 for light duty vehicles, for the first time. Additional standards which were introduced between 2004 and 2015 require a 19% improvement in L/100km. For developing the fuel economy standards, Japan used the “Top Runner” method. This method is totally different with the fuel economy standard strategy in other countries

(MEPS) (Wachter 2006). The implementing the stringency like fuel economy standards has increased by Japan in 2006. Hence, it is planned that Japan will decrease the CO_2 emission to 125 g/CO_2 m^3 (An, Gordon et al. 2007). Figure 2.8 demonstrates the target of some countries to reduce the CO_2 emission by implementing the fuel economy policies.

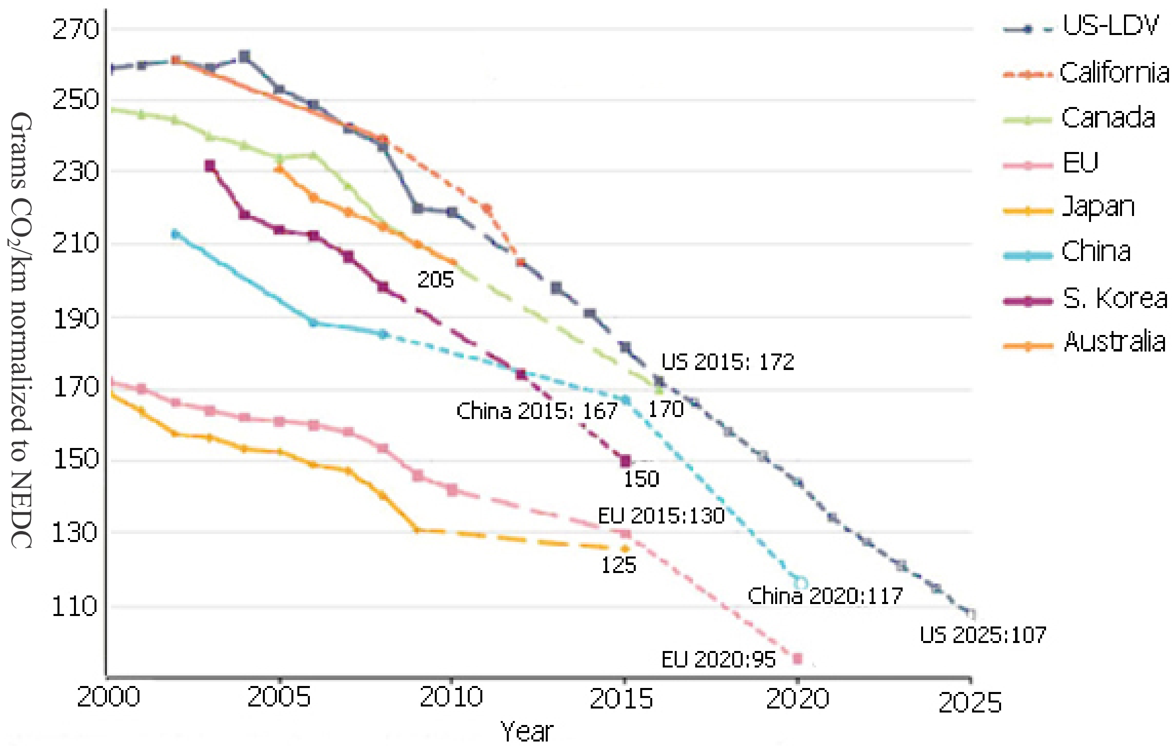


Fig 2.8.The target of some countries to reduce the CO_2 emission by implementing the fuel economy policies (ICCT 2011a)

2.3 Fuel Economy Label

A label is a voluntary or mandatory sticker that is attached to the vehicle which containing data on the fuel economy or fuel consumption of the motor vehicle. The consumers are able to select the more efficient models by the use of the labels information. For consumers that want to buy the most efficient vehicle these labels allow them to choose the best model with high efficiency. When different model efficiencies exist in the market, fuel economy labels will work effectively and play an important role. In different countries there are three kinds of labels that can be used, comparison, endorsement or a combination of both. An important role of labels is to inform consumers to find out the comparing similar units of vehicles. Actually the labels presents the fuel economy rating of a model with a scale that also ranks it between the lowest and highest fuel consuming model (Mahlia, Masjuki et al. 2002). Information on the fuel economy of motor vehicles is fundamental and essential if consumers are aware of the choices available to them. The fuel efficiency labels help the costumers in two ways; first it can help them to compare vehicle choices, second can help them to understand the tax implications and significances over the lifetime of the vehicle.

However the fuel economy label is just one part of a customer information strategy that increases the effect of buying behavior and fuel efficiency (Mahlia, Masjuki et al. 2002). A fuel economy label is a relatively cheap measure in order to affect consumer behavior to cause market transformation. In addition it causes to encourage motor vehicle manufacturers to produce vehicles that are more efficient.

2.3.1 United States Fuel Economy Label

Today there are a few countries that have executed fuel consumption or fuel economy labeling programs. The U.S has the longest running program of this type. Following picture indicates the current federal fuel economy label. Every new car that is sold in the U.S should have this label on its window. This label illustrates both the highway and city mileage and also combined mileage which is a combination of 55 percentage of the city and 45 percentage highway tests that show the local driving in the U.S. (EPA 2011; UNEP 2011). For new vehicles that starting with the 2013 model year, EPA recently redesigned the Fuel Economy and Environment Labels that must be attached. Manufacturers are allowed to start using the new labels in 2012 model year vehicles.

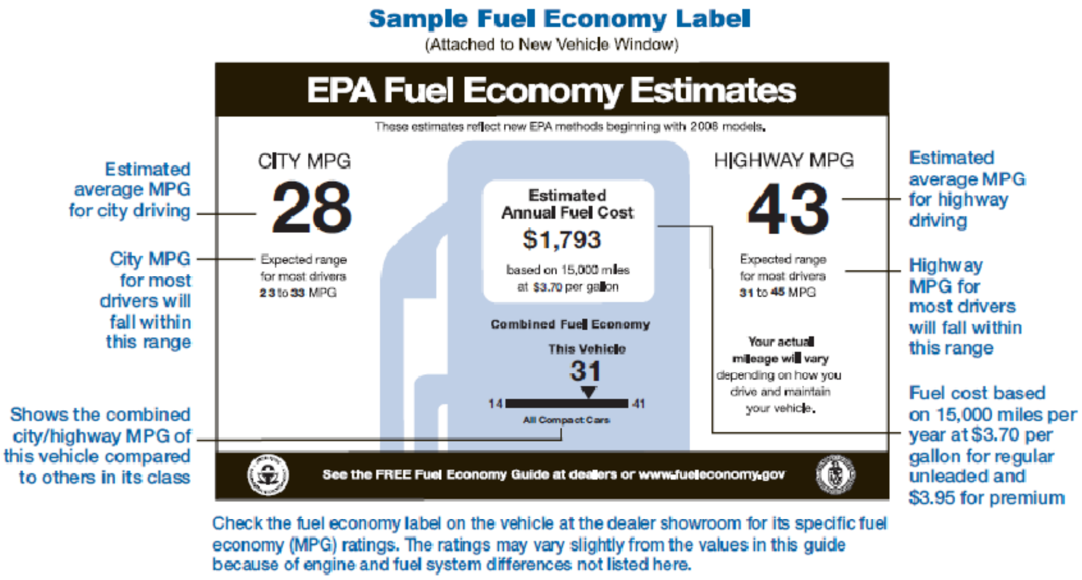


Fig 2.9.USA in use Label

A sample label for a gasoline vehicle is shown in the following picture. There are some small different designs that will be used for electric vehicles, plug-in hybrids and flexible-fuel vehicles (EPA 2011).

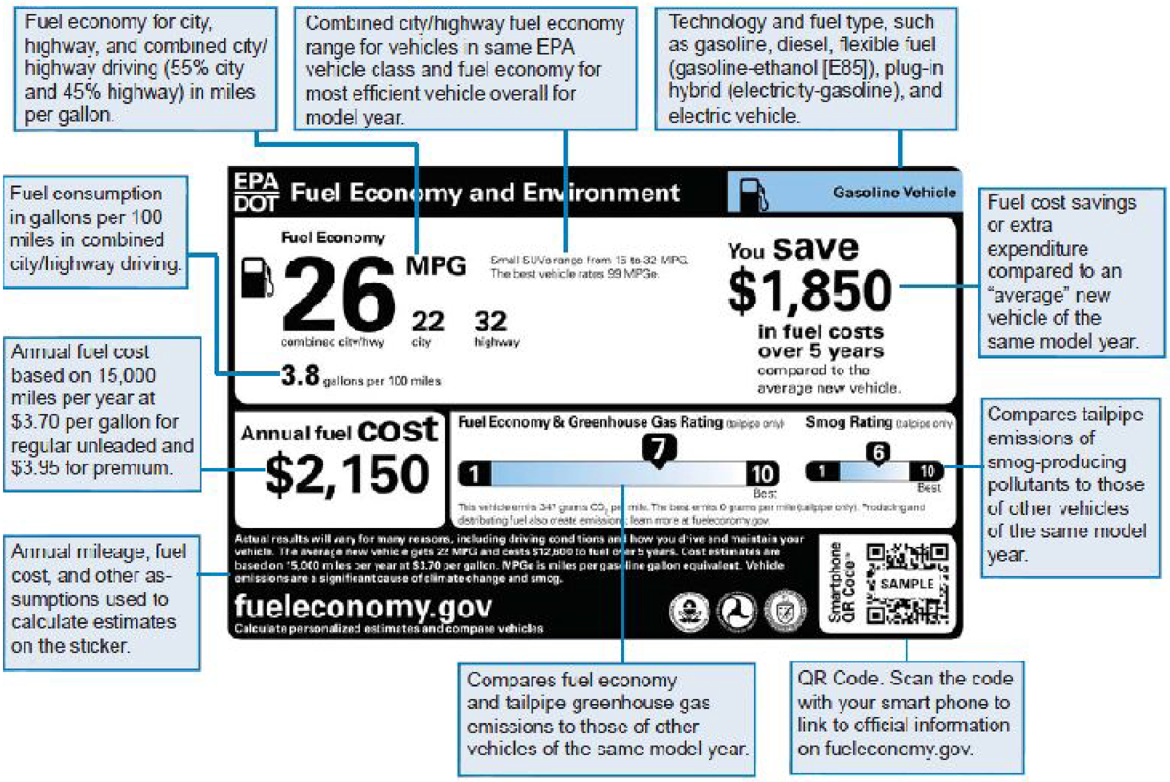


Fig 2.10.USA new Label for 2012

2.3.2 The California Label

California's Smog Index Label has helped consumers to evaluate the smog emissions from new cars which are related since 1978. The Environmental Performance (EP) Label determined the cleanest car easily by providing two scores which are a Smog Score and Global Warming Score. Both scores are ranking from the 1 to 10, in this case 10 shows the cleanest and 5 is presenting an average new vehicle (DriveClean 2011; UNEP 2011).

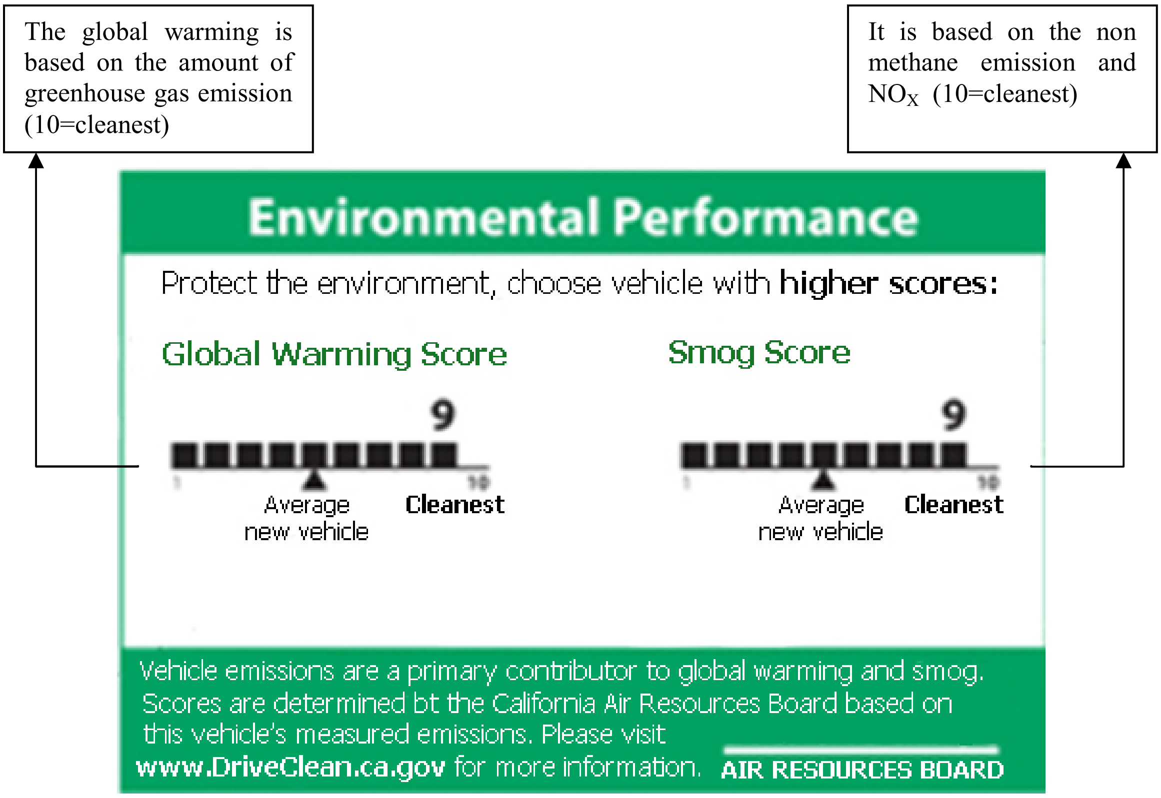


Fig 2.11.The California Label

2.3.3 The United Kingdom Label

A new "Green Label" has been introduced in the United Kingdom from July 2005. The "Green Label" is planning to let the costumers know about the impacts on environment by a special car. Moreover, it provides some simple ideas about how to start making real fuel savings without delay (VCA 2006).

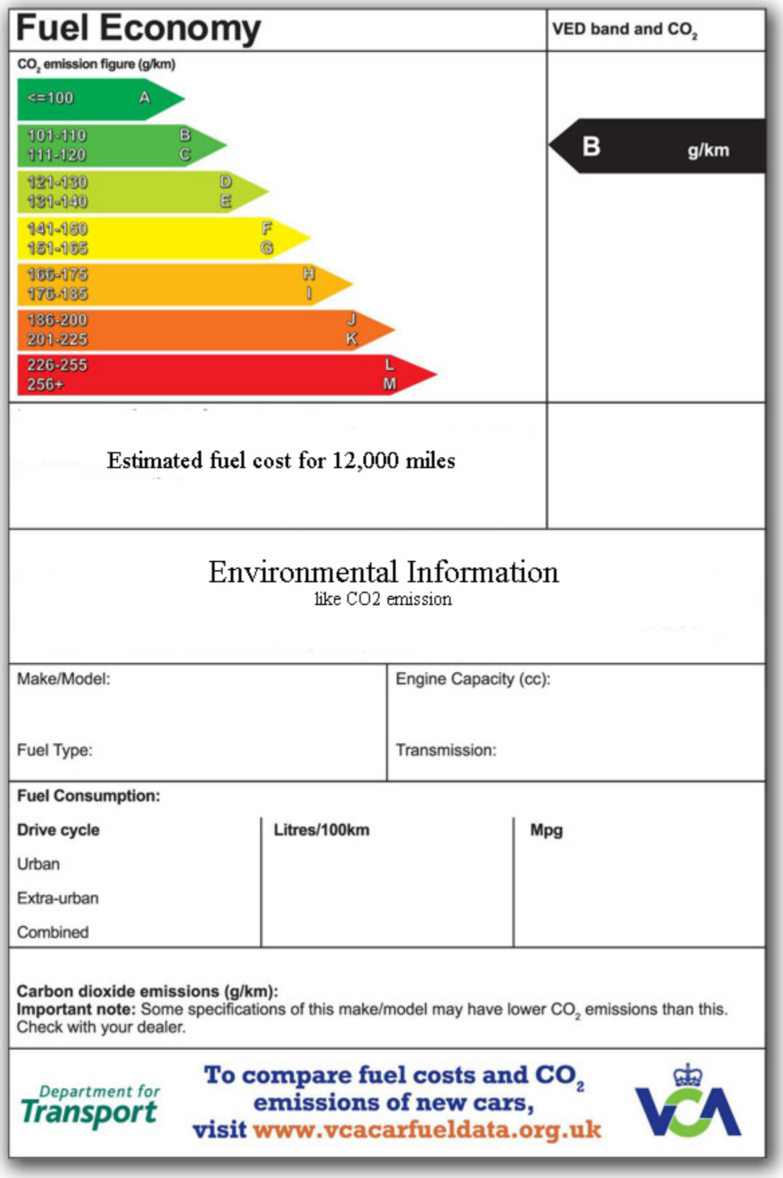


Fig 2.12.The United Kingdom Label

2.3.4 The South Africa Label

The South African car Industry with the Department of Minerals and Energy, has introduced a standard fuel economy and carbon dioxide emission testing for vehicles from 1st July 2008. The system is based on the usage in Europe, also it allows comparing of various models when it is testing under different parameters (EnergyRep.SouthAfrica 2011). The common label has demonstrated by the following figure in the South Africa. The fuel consumption recorded in liters per 100 km and carbon dioxide emissions values as determined by SANS 20101: 2006 grams per km respectively.

2.3.5 The Australia Label

A fuel consumption label is determined mandatory for vehicles, since April 2009. The new label exhibits three fuel consumptions which are: ‘urban’, ‘combined’ and ‘extra urban’ and also the CO_2 value. It also determines the higher fuel consumption of many cars which are used in urban. In Australia all new light duty vehicles that are sold must attach the Fuel Consumption Label on the window of their vehicles. The label determined the vehicle’s fuel consumption in the unit of L/100km and its emissions of CO_2 in the unit of g/km (AGS 2011; GreenVehicleGuide 2011).

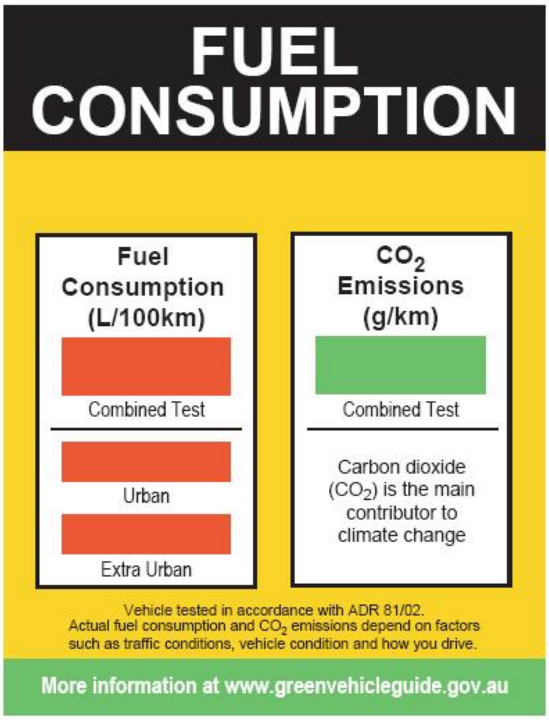


Fig 2.13.The Australia Label

2.3.6 The Singapore Label

In Singapore this is compulsory for registered motor vehicles to attach a Fuel Economy Label (FEL). Information on the FEL is based on the Certificate of Registration (COR) due to the model. Only the models that have the label are allowed to be present in the market (NEA 2002). The figure 2.14 presents the fuel economy label of Singapore.

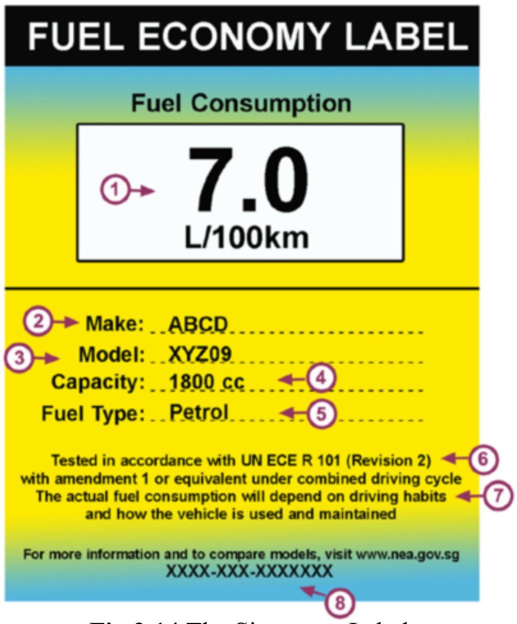


Fig 2.14.The Singapore Label

2.3.7 The New Zealand Label

The New Zealand has gathered the fuel economy data from the different importers of these models of vehicle:

- Imported vehicles manufactured after February 2005. 97% are tested by the European Standard and 3% by the Japanese Standard.
- Vehicles that registered previously, manufactured from January 2000 and imported after February 2005. They are tested by the Japanese Standard.

An open discussion has been started in order to find out the best option of fuel economy by Cabinet Business Committee that implementing a mandatory vehicle fuel economy labeling scheme was chosen (Fuelsaver 2009). This mandatory program was also proposed in the New Zealand Energy Efficiency's draft (NZEnergyCabinet 2008). The fuel economy label presents the fuel cost per year and fuel economy rating out of 6 stars. The unit of fuel economy rating is liters per 100km. Cars for sale were required to display information about the vehicle's fuel economy Since 7 April 2008.

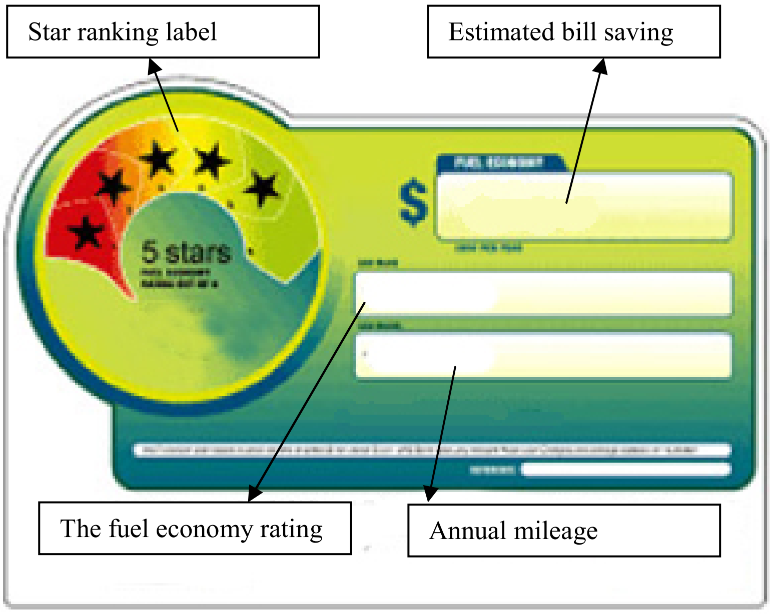


Fig 2.15.The New Zealand Label

2.3.8 The India Label

Since 2010 India has a voluntary fuel efficiency labeling system for new vehicles. By the march 2012 the implementing the fuel economy label will be mandatory (BEE 2011).

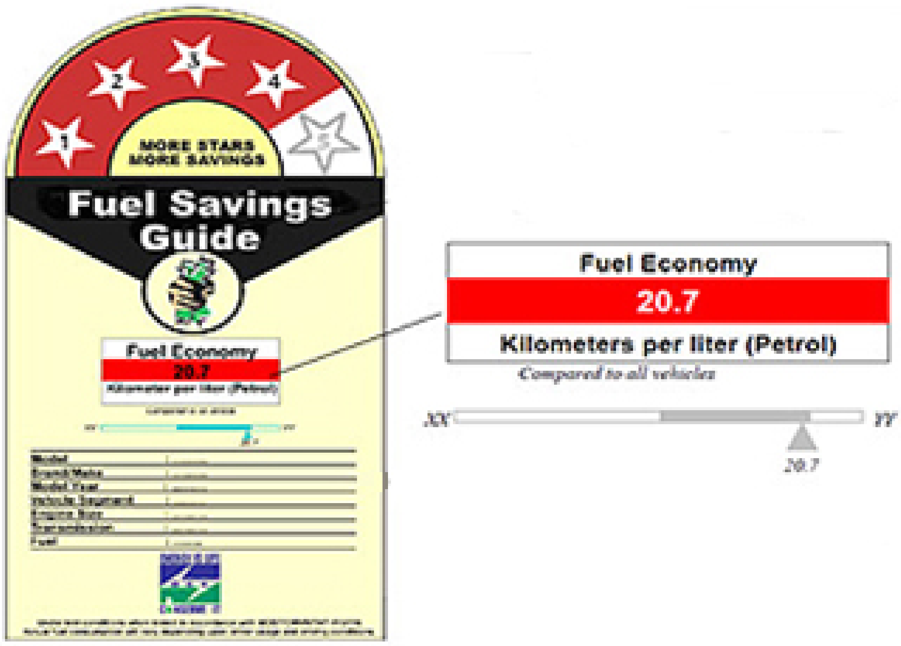


Fig 2.16.The India Label

CHAPTER 3
METHODOLOGY

Selecting an appropriate test procedure is the first step, in order to establish the fuel economy standards and labels. Test procedure is the fundamental of measuring the fuel economy or emission of motor vehicles. The measured data in the laboratory are the inputs information for setting the fuel economy standards and labels. To achieve the best result, the selected test procedure must be as similar as possible to the real-world driving cycle in a country. In the second step the fuel economy standards are determined based on fuel economy survey and test data. In order to set standards some approaches and analysis should be conducted (Turiel, Chan et al. 1997). In the next step, the fuel economy label can be developed. Consider to the collected data and obtained fuel economy standards, a suitable and understandable label can be determined. Finally, when the fuel economy standards and label are being implemented the impacts of fuel economy should be monitored. The achieved information from monitoring is necessary, in order to update and re-implement the fuel economy standards and label after a specific time.

3.1 Test procedure

A test procedure is a repeatable procedure or a standard laboratory test method which represents the real driving condition of a country. It is the fundamental of fuel economy standards and labels and it support them. If the test procedure is wrong, all the program will be ruined (Meier and Hill 1997). The manufacturers, regulatory authorities and also consumers are able to evaluate the fuel economy of different motor vehicles through test procedure. Fuel economy rating, fuel consumption, gas emissions and other required data for the examined motor vehicle can be obtained due to the driving cycle under the test procedure. This achieved data are vital for establishing an exact fuel economy standard.

Unfortunately, there is no specific test procedure in the ISO standards which is the International Organization for Standardization for the measurement of fuel consumption for motor vehicles. Therefore, in order to develop the test procedure, the adoption from other internationally recognized standard will be considered.

As mentioned before, there are three main standard procedures in order to determine fuel consumption and greenhouse gas emission such as USA cycle, New European Driving Cycle and Japan JC08 mode cycle.

In order to adopt these internationally recognized test cycles some factors must be taken into consideration. The condition of the local manufacturer, economic policies, trading market, climate of the region and also even local common driving behavior and pattern and driving frequency distributions must be consider, in order to develop or adopt a test procedure for a specific region or country. Another factor for adopting a test procedure is the maximum speed limit allowed for roads in the country. The maximum speed of the cycle must not be more than the speed limit in the local roads. Attention to conditions causes to gain accurate and perfect data that are the same as real driving condition and real fuel consumption. Actually, a test procedure should represent the actual usage condition. It also must over a wide range of vehicles with exact results. To modify easily and to be inexpensive, repeatable and comparable are other characteristics that a satisfactory test procedure should have (Mahlia, Masjuki et al. 2002). In fact, gathering all these characteristics sometime is impossible. Usually, a test with high accurate results and real condition is expensive or may unavailable.

Test procedures have at least two goals: (i) to rank the models by efficiency correctly and (ii) to provide accurate and perfect estimates of real in driving fuel consumption.

To accomplish a test procedure and achieve to the mentioned goals, driving cycle can be obtained through the real road routes testing. In order to resemble the real driving characteristics in a city, the suitable road routes must be selected. The most common driving behavior and also dominant traffic condition must be cover by selecting the suitable road routes. The road routes in a city can be picked up and chosen due to the researches that have been done about the roads. Usually the routes which are passing from one end of the city to the other side through the city downtown area, would cover the driving conditions (André 2006c; Nutramon and Supachart 2009).

3.2 Set the fuel economy standards and labels

The fuel economy standard is defined as governmental enacted standards that limits the least levels of efficiency, or highest levels of fuel consumption that the motor vehicles must have this condition in order to be sold legally (Mahlia, Masjuki et al. 2002a). The fuel economy standard determines the minimal required efficiency for vehicles. Actually, fuel economy standards puts a limitation for the manufacturer to produce motor vehicles with at least specific efficiency (McMahon and Turiel 1997). The certain line that divides efficient and inefficient available motor vehicles is indicated by fuel economy standards. The fuel economy standard inhibits the motor vehicle producer to manufacture low efficient cars.

The fuel economy standards and labels can be implemented mandatory or it can be set as voluntary plan. The fuel economy standards program can be signed between the government and a manufacturer. In order to support car companies and manufacturer fuel economy standards can be enacted in several stages. It means that policy makers give ample time to the local manufacture to achieve determined fuel efficiency. The desired fuel economy standards can be upgraded in several steps by planning the time of implementation. This causes improvement of local car manufacturer. Due this multi-stage planning gradually, the enacted standards will adapt with the international level of standards. Starting this plan with low efficiency improvement that prohibit manufacturing of few vehicles, encourages car companies to improve their technologies (Nadel 1997; Mahlia, Masjuki et al. 2002). In this case, it will be no hurt for local manufacturers and they may joint to licensing agreements with international car manufacturers in order to achieve new technologies and new designs. After few years, the fuel economy standards and labels can be implemented completely.

Some approaches are determined by researchers in order to implement the fuel economy standards and labels. Unfortunately, these approaches can be applied in developed countries because of the numerous required data. For developing countries with primary information the suitable approach that is developed by *Mahlia* can be used (Mahlia, Masjuki et al. 2002). This theory and methodology is used in this study.

Generally, the two major approaches (the economic/engineering and the statistical) are used to accomplish analyses and set standards (Turiel, Chan et al. 1997). The *Mahlia's* theory is a combination of the economic/engineering and the statistical approach. The statistical approach is used to set standards because the required data is easier to be obtained. In order to analyze the economic, energy impacts and environmental effects of the standards the economic/engineering approach is used which is more accurate. References (Koomey, Mahler et al. 1999; Mahlia, Masjuki et al. 2001; Masjuki, Mahlia et al. 2001; Mahlia, Masjuki et al. 2002) discussed and presented the basic equations for statistical and economic/engineering approaches.

3.2.1 Proposed fuel economy Standards

Before initiating the statistical or engineering approach some initial choices must be made. Depending upon the product usually they must be separated into several categories based on the engine capacity, weight or internal volume of vehicles. This categorization sometimes is known as product class. The classification of vehicles allows for differences in fuel consumption consider to the extra utility or features (Turiel, Chan et al. 1997). Generally, motor vehicles are classified due to the engine capacity.

The standard fuel economy rating can be determined, based on the average fuel economy rating in the year that the standards will be implemented (*average* FER_{Yse}). The equation 3.1 presents the calculation of standard fuel economy rating (FER_{STD}).

$$FER_{STD} = \sum \frac{FER_{Yse}}{n} \times (1 + \%STD) \tag{3.1}$$

The average fuel economy rating in the year of standards implementation can be obtained by using equation 3.2:

$$FER_{Yse} = FER_{i(Ysc)} \times (1 + AFI)^{(Yse - Ysc)} \tag{3.2}$$

where $FER_{i(Ysc)}$ is average fuel economy in the year that data is collected (Ysc) and AFI is annual fuel economy rating improvement. These two parameters can be evaluated by using equations 3.3 and 3.4, respectively. In order to obtain the results, some initial data such are needed such as the number of vehicles (Nv_i) and corresponding fuel consumption (FC_i).

$$FER_i = Ym \times \frac{Nv_i}{FC_i} \tag{3.3}$$

Ym = Annual mileage of motor vehicle (km)

$$AFI = \left(\frac{FER_i - FER_{i-1}}{FER_i} \right) \times 100 \tag{3.4}$$

3.2.2 Proposed fuel economy label

Nowadays, there are various methods and approaches, in order to improve the fuel economy of motor vehicles. One of the most effective approaches to improve the fuel economy of vehicle specially light duty vehicles is fuel economy label (Silitonga, Atabani et al. 2011). Fuel economy label is the most effective methods to increase the usage of more efficient vehicle and causes to reduce fuel consumption in the society. A fuel economy label is also a cheap method to effect costumer behavior on purchasing between the similar motor vehicles which have different fuel economy ratings (Raimund and Fickl 1999; Silitonga, Atabani et al. 2011). The fuel economy label which can be attached to the cars, gives essential information about the vehicle. This information causes awareness of costumers while they want to buy a vehicle. Focus on the fuel consumption or CO_2 reduction in labels, can influence on costumer easily. On the other hand, fuel economy label program also influences the market transformation (Fickl and Raimund 2000). The market transformation occurs due to changing the average fuel economy of available vehicles in the marketplace. It also encourage manufacturer to produce more efficient vehicles in order to be in competition with other car companies.

It is possible to represent a lot of data about vehicle on the label. In order to keep the label simple and easily understandable, some essential information must be presented on the label. Among the wide range of data, some information is recommended to be covered with the label (Fickl and Raimund 2000). The suggested essential information are:

- The characteristics of the model such as brand, type of fuel and etc.
- Fuel economy rating (km per liter, liters per 100 km, or miles per gallon)
- Determine fuel consumption of the model in comparison to the average fuel consumption of vehicles in market

- Information about CO_2 emission reduction

The simplicity of design and contents are important for the label which must ensures a good communication effect (Mariahilfer 2005). The representation of essential data on the label must be effective on the costumer in few seconds. It means that a well designed label never makes costumers confused. Therefore, a label especially for passenger cars must be simple, insensitive for manipulation, feasible and durable. In order to achieve the advantage of fuel economy standards and label program especially through the labeling, gathering the useful information based on available vehicles is important.

Generally, there are some types of labels such as bar rating, star rating and alphabetic. In order to choose a type of label for designing, the area that label wants to be applied must be considered. Actually, the most familiar type of label should be chosen for a country. If the costumers understand the label easily, they can make a great decision based on information given in the label. In summary, a proposed label for a country must be common type, understandable and workable and should have long-life and simple design.

3.3 Conduct a cost-efficiency analysis

3.3.1 Engineering analysis

As mentioned before, there are two methods that can be used to introduce fuel economy standards which are the economic/engineering method and the statistical one. There are different opinions about the disadvantages and advantages of each analysis. One of the advantages of the economic/engineering is being more accurate and intensive in data and it also includes the cost estimate analysis and determines the effects on manufacturers, costumers, and energy demand and also environment. The other advantage of this approach is that it considers the option of new design that it is not exist in current models and it also determined the possibility of some combination of different designs that can be achieved. The new design option and combination of designs causes high efficiency of the vehicle rather than the previous model.

The steps of approach for setting the standards are represented in the table 3.1 (Turiel, Chan et al. 1997).

Table 3.1.Steps of engineering analysis

No.	Steps for engineering analysis
1	Select the class of vehicle
2	Choose the baseline units
3	Determine design options for each class
4	Evaluate fuel economy improvement due to the each design option
5	Combine design options and determine fuel economy improvement
6	Analysis the cost estimates for selected design option
7	Draw the cost-efficiency curves

According to the table 1 for analyzing, the classes of motor vehicles must be determined. Usually the classification of the passenger cars is based on the capacity of the engine. In this case also the classes of motor vehicles should be determined by capacity of the engine. In the next step the baseline model for each class must be identified. The baseline model for a class of motor vehicle is a model which has efficiency equal to the average of the existing models or the minimum amount of efficiency. It is recommended, that the least efficient model must be chosen as the baseline mode (Turiel, Chan et al. 1997; Mahlia, Masjuki et al. 2002). The third step is determining the design options. The design options are known as possible changes to the design of the baseline model that will improve efficiency of the vehicle. The potential improved design options can be determined due to the collected information and also consider to the manufacturers' suggestion. The substitution of the more efficient component to the baseline product is considered as potential design option selection (Newnan, Eschenbach et al. 2004). These options can be added to the baseline separately or also in combinations.

The efficiency improvement of each design option is determined through calculating potential improvement from component substitutions to the baseline models. For motor vehicles, the efficiency improvement is calculated based on the potential design options for improving fuel economy rating (*EER)*.

The maximum technologically workable design option is a combination of individual design options (Biermayer 1996). These individual design options can be identified for each class of motor vehicles. This method results in the highest fuel economy rating. These design options with great efficiency level must be commercially feasible and also available as manufacturing.

By using the manufacturer data and engineering calculation the achieved efficiency level corresponding to different design options can be evaluated.
For combined design options the summation of individual design option costs is equal to the total expenses. In fact, the combination design option is the cumulative changes to the baseline model that its fuel economy rating is improved. The cumulative improvement of each design option can be used as the fuel economy rating improvement of combination design options.

The summation of incremental price of each design option can be used for cost estimating of combined design option. The results of this engineering analysis can be presented in the cost-efficiency curves (Biermayer 1996). These curves show incremental manufacturer cost of the design options corresponding to the fuel economy improvement.

3.3.2 Life cycle cost analysis

After the completion of the engineering analysis, it is necessary to evaluate the economic effect of the potential fuel economy improvement by using the consumer life cycle cost analysis.

The life cycle cost (*LCC*) is the summation of the purchase price (*PC*) and the annual operating cost (*OC*) discounted over the lifespan (*N, in years*) of motor vehicles. If operating expense is constant over time, the summarized equation for calculating the LCC is (Turiel, Chan et al. 1997):

$$LCC = PC + PWF \times OC \tag{3.5}$$

where PWF is the present worth factor that can be calculated by equation 3.6.

$$PWF = \frac{1}{r}\left[1 - \frac{1}{(1+r)^N}\right] \tag{3.6}$$

For indicating the present value of future energy cost savings, it is essential to use the discount rate (r) in LCC analysis. The LCC analysis also includes installation and maintenance costs. The operation cost includes maintenance cost and annual fuel consumption cost and other annual necessary expenses for motor vehicle. The installation cost is covered with the initial price of motor vehicle. The equation 3.7 presents the operating cost.

$$OC = \left(\frac{Ym \times PF}{FER}\right) + MC \tag{3.7}$$

OC = Annual operating cost (Rials)
FER = Fuel economy rating (km/L)
Ym = Annual mileage (km)
PF = Fuel Price (Rials)
MC = Annual maintenance cost (Rials)

A policy maker can choose the standard which is located beyond the LCC minimum in direct to the baseline according to the LCC curves, if it is supposed only to maximize the fuel consumption (Turiel, Chan et al. 1997).

3.3.3 The payback analysis

The payback period (*PAY*) is defined as the required amount of time in order to recover the initial investment on the fuel economy improvement. In this study the operating cost (*OC*) is assumed constant for each design option (Turiel, Chan et al. 1997), therefore the payback is a fraction of the increase in the purchase price and installation cost (*PC*) and annual operating expenses.

$$PAY = -\frac{\Delta PC}{\Delta OC} \tag{3.8}$$

The purchase price which is increased will not be recovered, if the payback period is greater than the lifespan of vehicle.

3.4 The market transformation prediction

The information about the fuel economy, fuel consumption, emission and etc that all are appeared on label, influence the costumers' decision. Usually, costumers decide to buy a better vehicle due to the fuel economy rating and less CO_2 emission (Mariahilfer 2005). Therefore, the appropriate fuel label increases the chance of more efficient vehicle to be sold. After few years gradually the number of more efficient vehicles will increase and the average fuel economy rating improves. On the other hand, car manufacturers are encouraged by the fuel economy label to produce motor vehicles with high efficient. All of these issues cause to transformation of market as can be seen in figure 3.1 (Saidur and Mahlia 2010). This market transformation can be predicted through evaluating the present average fuel economy rating, standards average fuel economy rating and labels average fuel economy rating.

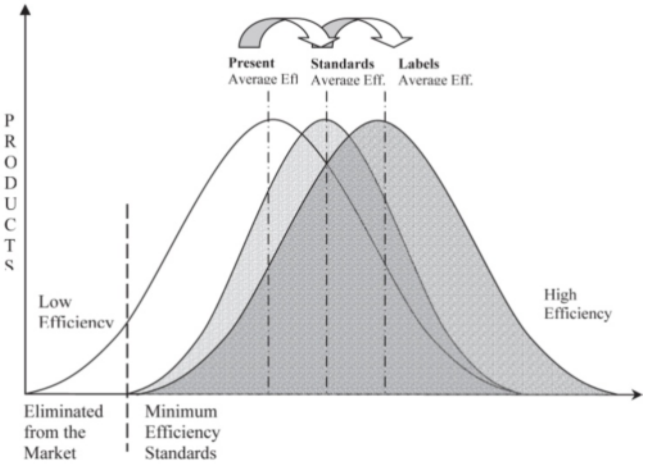


Fig.3.1. The market transformation schematic

The baseline average fuel economy rating is the average existing vehicles fuel economy rating before standards and labels is implemented, in the market. The average *FER* is determined due to survey data from market in a certain year, that can be predicted for the year of standards enacted (White, Agee et al. 1998). The equation 3.9 presents the calculation of average fuel economy rating in the year that standards will be implemented.

$$FER_{PAF} = \frac{1}{n}\sum_{i=1}^{n} FER_{Ysc} \times \left(1 + AFI_i\right)^{\left(Yse_i - Ysc\right)} \qquad (3.9)$$

FER_{PAF} = Present average fuel economy rating of motor vehicle

FER_{Ysc} = Fuel economy rating in the year of survey conducted for motor vehicles

AFI_i = Annual fuel economy ratings improvement (%)

Y_{sei} = Year that standards will be implemented

Y_{SC} =Year survey conducted

n = number of motor vehicles

The standard average fuel economy rating can be calculated by using equation 3.10. The information about vehicles especially the fuel economy rating is valid only for the year of the survey conducted.

$$FER_{SAF} = \frac{1}{n}\sum_{i=1}^{n} FER_{STD} \tag{3.10}$$

FER_{SAF} = Standards average fuel economy rating of motor vehicles

FER_{STD} = Fuel economy rating in the year of standards implementation

n = number of motor vehicles

Depend on the type of fuel economy label, the fuel economy rating of each vehicle is determined with grade A to G or number of stars. The central amount of the grade in the labels can be chosen for calculating the market transformation (Efficiency 1999). By simplifying the grades the transformation can be evaluated by using equation 3.11.

$$FER_{LAF} = FER_{Avg} \times (1 + \%\delta) \tag{3.11}$$

3.5 Impacts of the fuel economy standards and label

The fuel economy standards and labels program has positive effects on the fuel economy rating of motor vehicles. This effect is not the only result of fuel economy standards and labels implementing. In the following section other effects of executing this program are presented.

3.5.1 The impacts of the fuel economy standards

The fuel economy standards improve the average fuel economy rating of vehicles. It means that the fuel consumption can be reduced. Therefore, the impacts of the fuel economy standard are: potential fuel savings, economic savings and also potential environmental impact.

3.5.1.1 Potential fuel savings (standards)

One of the most important of fuel economy standards is decreasing the fuel consumption. This decline of fuel consumption causes to fuel saving during the years that fuel economy standards are being implemented. In the following sections some essential formulas are presented in order to predicted the potential fuel saving.

The multiplication of scaling factor (SF_i) and the unit fuel savings of vehicles (UFS_i) and applicable stock (AS_i) in the year (i) after standards implemented, is equal to the fuel saving (FS_i) due to the implementation of fuel economy standards (Saidur and Mahlia 2010).

$$FS_i = \sum_{i=S}^{T} AS_i \times UFS_i \times SF_i \tag{3.12}$$

where the AS_i, UFS_i and SF_i are applicable stock, the unit fuel saving and the scaling factor, in the specific year i respectively. These concepts are explained as follow.

1) Applicable stock

The applicable stock is a concept of the number of motor vehicles which are influenced by the standards in the specific year. The applicable stock is equal to the shipment survival factor (SSF_i) multiplied by the shipments in the particular year (Sh_i) plus the applicable stock in the previous year (AS_{i-1}). The equation 3.13 presents the mathematical formulation.

$$AS_i = (Sh_i \times SSF_i) + AS_{i-1} \tag{3.13}$$

1.2) Shipment

The difference between the numbers of motor vehicles in predicting years minus the vehicles in the previous year plus the number of retired motor vehicles is known as shipment (Sh_i). In the following equation Nv_i is the number of vehicles in the specific year i and L is the lifespan of motor vehicles (Silitonga, Atabani et al. 2011):

$$Sh_i = (Nv_i - Nv_{i-1}) + Nv_{i-L} \tag{3.14}$$

1.3) Shipment survival factor

The shipment survival factor is a function of the retirement formulation and annual retirement rate. The shipment survival factor will be equal to 1, if the duration of standards setting is shorter than 2/3 of the lifetime of the vehicle (Mahlia, Masjuki et al. 2002). The equation 3.15 shows the mathematical formulation of Shipment survival factor.

$$SSF_i = 1 - \left[\frac{(Yse_i - Ysh_i) - \frac{2}{3} L}{\left(\frac{4}{3} - \frac{2}{3}\right) L} \right] \tag{3.15}$$

2) Unit fuel savings

The unit energy savings is equal to initial fuel saving in the years standards enacted (UFS_S) multiplied scaling factor (Saidur and Mahlia 2010).

$$UFS_i = SF_i \times UFS_S \tag{3.16}$$

3) Scaling factor

The scaling factor accounts the natural improvement of efficiency (Koomey, Mahler et al. 1999). In fact this factor determines the amount of efficiency improvement of motor vehicles in the absence of standards. The scaling factor scales down the incremental cost and the unit fuel savings linearly to zero over the useful lifespan of the standards.

$$SF_i = 1 - (Ysh_i - Yse_i) \times \frac{AFI}{TI_S} \tag{3.17}$$

Ysh_i = Year i of shipment of motor vehicle

Yse_i = Year standard is proposed

3.1) Total fuel economy improvement

The total fuel economy improvement is the fraction of Initial unit fuel savings and baseline fuel consumption in the year that standards will be implemented. The equation 3.18 expresses the mathematical formulation of the total fuel economy improvement.

$$TI_S = \frac{UFS_S}{BFC_S} \times 100 \qquad (3.18)$$

3.2) Initial unit fuel savings

The difference between standard fuel consumption of passenger car and baseline fuel consumption, is known as initial fuel saving. The equation 3.19 shows the calculation of initial unit fuel saving.

$$UFS_S = BFC_s - SFC_{mv} \qquad (3.19)$$

3.5.1.2 Potential economic savings (standards)

The potential cumulative present value, bill savings and the net savings are the economic impacts of fuel economy standards. These impacts are based on investment and the fuel savings for motor vehicles with higher efficiency.

1) Potential bill savings

The multiplication of average fuel price by the total fuel savings is equal to the bill saving. The potential bill saving can be calculated by using equation 3.20:

$$BS_i = FS_i \times PF_i \qquad (3.20)$$

2) Net savings

The major economic indicator that is used in this approach is net saving. One of the methods for calculating the net saving is annualized costs which smoothes the net savings over time (Mahlia, Masjuki et al. 2002). The annualized net dollar savings in a specific year is calculated by equation 3.21. In this equation the capital recovery factor

(CRF) and the initial incremental cost (IIC) is evaluated by using the equations 3.22 and 3.23, respectively.

$$ANS_i = FS_i \times PF_i \ -\sum_{i=S}^{T} AS_i \times CRF \times SF_i \times IIC \tag{3.21}$$

2.1) Capital recovery factor

$$CRF = \frac{d}{\left[1-(1+d)^{-L}\right]} \tag{3.22}$$

d = the interest rate for each year (%)
L = Lifespan of motor vehicle

$$IIC_S = UFS_S \times IC \tag{3.23}$$

IC = Incremental cost of motor vehicle (Rials)

3) Cumulative present value

The equation 3.24 is used to calculate the cumulative present value due to the annualized net savings, consider to the percentage real discount rate.

$$PV(ANS_i) = \sum_{i=S}^{T} \frac{ANS_i}{(1+d)^{(i-Ydr)}} \tag{3.24}$$

3.5.1.3 Potential environmental impact (standards)

The potential reduction in gasses emissions which have negative impacts on the environment is the positive effect of standards. According to the measured amount of gas emission per liter of fuel consumption, the gas emission can be evaluated. The potential reduction of emission is a function of fuel saving (*FS_i*) multiplied by the emission factor of each gas (*Em_g*) due to the fuel consumption.

$$ER_{ig} = FS_i \times Em_g \tag{3.25}$$

3.5.2 The impacts of the fuel economy label

The impacts of the fuel economy label include: the fuel savings, potential economic savings and the potential environmental impact. The prediction the impacts of fuel economy label depend on the grade that may selected by costumers when they buy the motor vehicle (Mahlia, Masjuki et al. 2002). The same as fuel economy standards, there are some calculations in order to evaluate the impacts of the fuel economy label. These calculations are presented as follow.

3.5.2.1 Potential fuel savings (label)

The different between calculations of impacts due to standards and also labels is that fuel economy labels are not influenced by the scaling factor (Mahlia, Masjuki et al. 2002). The standards fuel consumption should be the baseline of the labels. There is no scaling factor for fuel saving due to the labels because the label baseline (standard fuel consumption) is static.

1) Potential fuel savings

The multiplication of the number of motor vehicles influenced by the labels in the specific year by the unit energy savings due to labels grade, is known as potential fuel saving.

$$FS_i = \sum_{i=S}^{T} AS_i \times UFS_i \qquad (3.26)$$

2) Applicable stock

Since the effective period of the labels (due to the fuel economy standards implementation) is shorter than 2/3 of lifespan motor vehicle, therefore the applicable stock is the shipments in a specific year (Sh_i) plus the number of motor vehicles affected by labels in the previous year (AS_{i-1}).

$$AS_i = Sh_i + AS_{i-1} \quad (3.27)$$

3) Shipment

The equation 3.28 expresses the calculation of the shipment which is the same as fuel economy standards.

$$Sh_i = (Nv_i - Nv_{i-1}) + Nv_{i-L} \quad (3.28)$$

4) Initial unit fuel savings

The initial unit fuel savings is equal to the difference between the annual unit fuel consumption of labels and the unit fuel consumption of the averages by standards which is assumed as baseline fuel consumption for labels.

$$UFS_i = BFC_l - LFC_i \quad (3.29)$$

5) Label fuel consumption

The labels fuel consumption can be predicted due to the label grades. The percentage improvement of the labels grade multiplied by the standards energy consumption is defined as label fuel consumption.

$$LFC_{MV} = SFC_{MV} \times (1 - \eta_l) \quad (3.30)$$

SFC_{MV} = Fuel consumption standards of vehicles (liters/year)

LFC_{MV} = Label fuel consumption (liters/year)

η_l = Percentage fuel economy label improvement of motor vehicle (%)

6) Baseline fuel consumption

The baseline fuel consumption is the standards fuel consumption and it is used to calculate the fuel impact due to the labels.

3.5.2.2 Potential economic savings (label)

The economic effect is actually a function of the fuel savings according to the fuel economy labels. The economic variables are clarified as follow.

1) Potential bill savings

The bill saving is equal to the fuel price multiplied by the total fuel savings due to the fuel economy label.

2) Net savings

Since the standards fuel consumption is used as a baseline for fuel economy labels, the scaling factor is eliminated from the calculation (Mahlia, Masjuki et al. 2002). Therefore, the annualized net dollar savings in a specific year which is the most important economic indicator can be calculated using equation 3.31.

$$ANS_i = FS_i \times PF_i - \sum_{i=S}^{T} AS_i \times CRF \times IIC \qquad (3.31)$$

where the capital recovery factor (CRF) and the initial incremental cost (IIC) can be evaluated by using the equation 3.22 and 3.23 ,respectively.

3) Cumulative present value

The cumulative present value due to the annualized net savings the same as fuel economy standards can be determined by using the equation 3.24.

3.5.2.3 Potential environmental impact (label)

As mentioned before the fuel economy label influences on the customers' decision. By using the more number of high efficient vehicles, the gas emission reduces. Therefore the same as fuel economy standards the potential reduction of emission can be calculated using equation 3.25. It must be consider that the fuel saving corresponding to the fuel economy label must be substitute in the equation.

3.5.3 Impacts of the implementing the fuel economy standards with label

The total impact of the fuel economy standards and labels is the summation of impact of each program. The method to achieve the effect of fuel economy standards and labels is discussed separately in the previous section.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Introduction

In this section the outcomes of research are presented. The obtained fuel economy standards, fuel economy labels, test procedure and market transformation are discussed in the case study of Iran. The results of the impacts of fuel economy standards and labels on the energy saving, economic saving and environmental effects are presented. In order to develop the fuel economy standards and label and to evaluate the potential impacts of this program, the statistical analysis and the economic/engineering approach are carried out, respectively. The fuel economy standards are determined based on the calculated data about 247 of available motor vehicles in Iran. The appropriate type of label due to the conditions of Iran is selected. The ranges of the grades on chosen bar ranking label for each class, are determined. At the end, results of calculations due to implementing this program such as fuel saving, economic saving and the positive effects on the environment and the market transformation are presented.

In order to start analysis an intensive data collecting is required. Data such as the motor vehicle manufacturer, model, engine size and fuel economy rating of motor vehicles are vital. Consider to the related published articles and books some initial data are gathered. Also in this research the exact information about 247 models are collected from related institute such as the fuel consumption optimizing organization. Some data of fuel economy rating of vehicles in Iran are obtained from the transportation data book. This book is published annually by the fuel consumption optimizing organization of Iran. Some data about energy demand, energy consumption and number of the road fleets are obtained from National Energy Balance of Iran.

4.2 Select the suitable test procedure

In order to develop or adopt a test procedure for light duty vehicles in Iran, some issues should be considered such as trading market, climate, traffic situation and the local driving behavior. A specific test procedure also can obtain by different laboratory test or by the real road testing. Generally as mentioned in chapter 2.1, there are three main test cycles that are being used in the world (USA, European and Japanese driving cycles).

Consider to the driving condition in Iran such as the limitation of speeds in roads and highways and due to the trade market policy in Iran, the European test cycle can be chosen. There are many cars and motor vehicles in Iran that are made in Europe countries. Actually, the European cars have large contribution in the market of Iran. The Iran-khodro that is one of the biggest car manufacturer in Iran, signed a contract with the Peugeot Company in France. Therefore, the European driving cycle is the most suitable test procedure in Iran. The details of the NEDC (New European Drive Cycle) driving cycle are presented as follow. The figure 1 shows the NEDC driving cycle of test procedure that is proposed to be used in Iran.

The NEDC driving cycle includes four repeated ECE-15 driving cycles and one segment EUDC cycle at the end. The total duration of test cycle and the whole distance are 1220 sec and 11.007 km, respectively. According to the figure 4.1, the average velocity and maximum speed for part one are 18.7 km/h and 50 km/h, respectively. The average speed of part two is 62.6 km/h and the maximum speed for this part is 120 km/h.

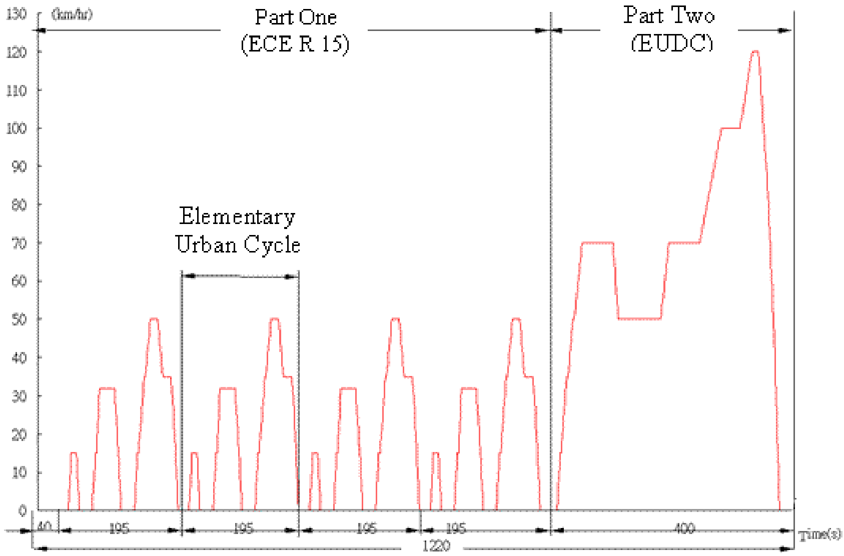


Fig. 4.1.Selected test cycle

4.3 Propose suitable fuel economy standards and labels

The fuel economy standards put a limitation for manufacturers to produce motor vehicles with the least specific efficiency. The motor vehicles with efficiency less than the standards efficiency must be removed from the market.

4.3.1 Proposed fuel economy Standards

The light duty vehicles in Iran are classified due to the engine capacity. This classification is tabulated in table 4.1.

Table 4.1.The classification of light duty vehicles in Iran

Class	Engine Capacity (c.c.)
1	below 1000
2	1000-1300
3	1300-1400
4	1400-1500
5	1500-1600
6	1600-1800
7	1800-2000
8	2000-2200
9	2200-2400
10	2400-3000
11	above 3000

According to the *Mahlia's* theory the statistical approach is used to determine the fuel economy standards (Mahlia, Masjuki et al. 2002). Table 4.2 shows the number of available vehicle and corresponding fuel consumption in each year.

Table 4.2.Collected data (number of vehicles and fuel consumption in each year)

Year	No. Vehicle	Consumption (million lit)
1998	3,049,048	10,320.36
1999	3,235,959	11,210.98
2000	3,444,226	11,649.50
2001	3,699,883	12,687.99
2002	4,009,528	13,575.22
2003	4,527,423	14,899.25
2004	5,217,202	16,466.34
2005	6,069,208	17,730.89
2006	6,964,421	19,585.23
2007	7,880,001	21,468.46
2008	8,726,500	18,840.78

Based on collected data that are tabulated in Table 4.2 and annual mileage of around 20,000 km, the average fuel economy can be calculated for each year (see equation 3.3). The annual fuel economy rating improvement (AFI) can be determined due to the obtained amount of average fuel economy rating for each year. By using equation 3.4 the AFI is found. Table 4.3 shows the result of this calculation. The sample of calculation is presented in appendix C.

Table 4.3.Average Fuel economy rating Improvement

Year	FER_i	AFI(%)
1998	5.9088	-
1999	5.7728	-2.356
2000	5.9131	2.372
2001	5.8321	-1.389
2002	5.9071	1.270
2003	6.0774	2.801
2004	6.3368	4.094
2005	6.8459	7.437
2006	7.1119	3.740
2007	7.3317	2.998
2008	9.2634	20.853
Average		4.18

The average fuel economy rating can be calculated, according to the gathered data about around 247 models of motor vehicles in the market of Iran. These collected data which include the fuel economy rating of each model of motor vehicles due to the engine capacity, are presented in appendix B. These information are survey data in 2008. Table 4.4 presents the achieved average fuel economy rating consider to the each class of motor vehicles.

Table 4.4.Average fuel economy rating for each class

Class	Engine Capacity	Avg FER
1	below1000	17.3
2	1000-1300	15.8
3	1300-1400	15.2
4	1400-1500	13.5
5	1500-1600	13.4
6	1600-1800	12.6
7	1800-2000	12.2
8	2000-2200	13.2
9	2200-2400	9.1
10	2400-3000	10.2
11	above3000	9.2

Therefore, based on the above results, the fuel economy rating in the year of standards implementation can be determined. The equation 4.1 shows the corresponding calculation. The year of collecting data is 2008 and the year that the fuel economy standards and labels are supposed to implement is 2013.

$$FER_{2013} = FER_{2008} \times (1 + 0.0418)^{(2013-2008)} \qquad (4.1)$$

The standard fuel economy rating is a percentage improvement from the average fuel economy rating in the year that the standards will be implemented. For setting the standard for motor vehicles in each class, the standard fuel economy rating is supposed to be 5%, 10% or even 20% more than the calculated average fuel economy. In order to have a positive effect on the fuel consumption and preventing of the hurt of local manufacturers, the 5% improvement is proposed for standards. According to the cost-efficiency analysis and the percentage of fuel economy rating improvement of the baseline unit in each class the proposed 5% standards improvement is reasonable that can be overcome by using current technologies. In addition, it helps the manufacturer to achieve to the standard and the program has the positive effect on the market. It supports the local motor vehicle producers. Table 4.5 represents the fuel economy standards rating for each class of light duty vehicles in Iran. The standards fuel economy rating is calculated based on both unit km/L and L/100km, the most common unit in Iran is L/100km.

Table 4.5.The fuel economy standards rating for each (5% class improvement)

Class	Engine Capacity	Avg FER	Standard FER (km/L)	Standard FER (L/100km)
1	below1000	17.3	22.2	4.5
2	1000-1300	15.8	20.3	4.9
3	1300-1400	15.2	19.6	5.1
4	1400-1500	13.5	17.4	5.7
5	1500-1600	13.4	17.3	5.8
6	1600-1800	12.6	16.2	6.2
7	1800-2000	12.2	15.7	6.4
8	2000-2200	13.2	17.0	5.9
9	2200-2400	9.1	11.7	8.5
10	2400-3000	10.2	13.2	7.6
11	above3000	9.2	11.8	8.5

4.3.2 Proposed fuel economy label

In order to have an appropriate effect on the costumers, the label must be adapted with condition of the country. Based on common type of label in Iran, the bar ranking label is selected as proposed fuel economy label. This label shows the fuel economy rating of each motor vehicle due to the determined grade. As can be seen in figure 4.2 the label has seven grade from A to G that they indicate the most efficient and inefficient vehicles, respectively. The size of the label is 105 mm (width) by 140 (height). It must be attached on the left–top corner of the front windshield. Some other information is also covered with this label such as CO_2 emission, brand and type of fuel, the manufacturer and the capacity of the engine.

According to the chosen bar rating label for light duty vehicles in Iran, the table 4.6 is used to determine the amount of each grade on label.

Table 4.6.Range of FER for each grade of label

Grade	Range FER (km/L)
A	FER < 20% less than STD FER
B	20% less than STD FER < FER < 10% less than STD FER
C	10% less than STD FER < FER < 5% less than STD FER
D	5% less than STD FER < FER < 5% more than STD FER
E	5% more than STD FER < FER < 10% more than STD FER
F	10% more than STD FER < FER < 20% more than STD FER
G	20% more than STD FER < FER < 25% more than STD FER

Consider to the above table and fuel economy standard for each class the range of each grade for labels can be obtained. In the bar rating labels the standards fuel economy gets the grade D. Therefore, the amount range of each grade in each class is calculated and the results are represented in tables 4.7 to 4.13.

Table 4.7.Fuel economy bar ranking for class 1

Grade	Range
A	FER <= 3.6
B	3.6 <FER <= 4.0
C	4.0 < FER <= 4.3
D	4.3 < FER <= 4.7
E	4.7 < FER <= 4.9
F	4.9< FER < =5.4
G	5.4 < FER <= 5.6

Table 4.8.Fuel economy bar ranking for class 2

Grade	Range
A	FER <= 3.9
B	3.9<FER <= 4.4
C	4.4 < FER <= 4.7
D	4.7 < FER <= 5.2
E	5.2 < FER <= 5.4
F	5.4< FER < =5.9
G	5.9 < FER <= 6.2

Table 4.9.Fuel economy bar ranking for class 3

Grade	Range
A	FER <= 4.1
B	4.1<FER <= 4.6
C	4.6 < FER <= 4.9
D	4.9 < FER <= 5.4
E	5.4 < FER <= 5.6
F	5.6< FER < =6.1
G	6.1< FER <=6.4

Table 4.10.Fuel economy bar ranking for class 4

Grade	Range
A	FER <= 4.6
B	4.6 <FER <= 5.2
C	5.2 < FER <= 5.5
D	5.5< FER <= 6.0
E	6.0 < FER <= 6.3
F	6.3< FER < =6.9
G	6.9 < FER <= 7.2

Table 4.11.Fuel economy bar ranking for class 5

Grade	Range
A	FER <= 4.6
B	4.6<FER <= 5.2
C	5.2 < FER <= 5.5
D	5.5< FER <= 6.1
E	6.1< FER <= 6.4
F	6.4< FER < =6.9
G	6.9 < FER <=7.2

Table 4.12.Fuel economy bar ranking for class 6

Grade	Range
A	FER <= 4.9
B	4.9 <FER <= 5.5
C	5.5 < FER <= 5.8
D	5.8< FER <= 6.5
E	6.5 < FER <=6.8
F	6.8< FER < =7.4
G	7.4< FER <= 7.7

Table 4.13.Fuel economy bar ranking for class 7

Grade	Range
A	FER <= 5.1
B	5.1<FER <= 5.7
C	5.7< FER <= 6.0
D	6.0 < FER <= 6.7
E	6.7< FER <= 7.0
F	7.0< FER < =7.6
G	7.6< FER <= 7.9

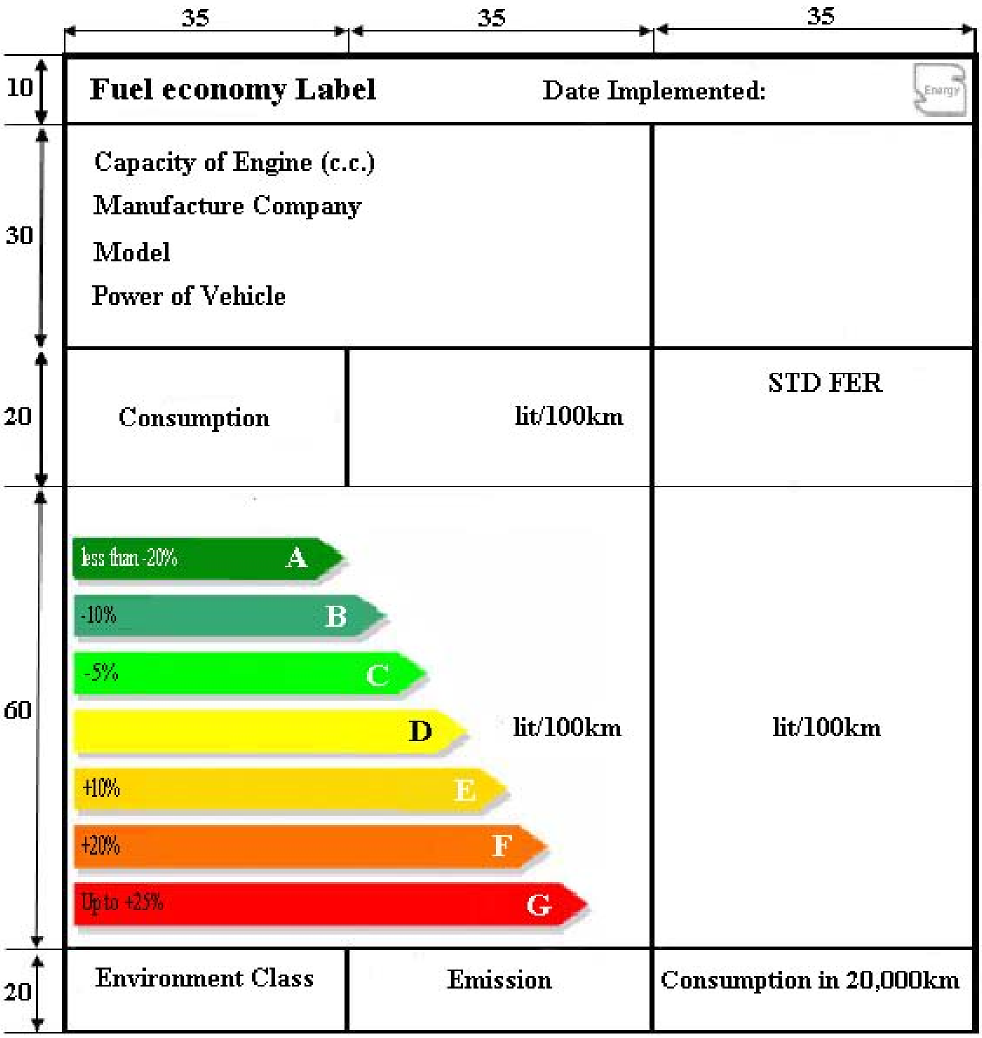


Fig 4.2. The Proposed Fuel Economy Label (*English*) – *the measures are in mm*

4.4 Conduct a cost-efficiency analysis

There are some steps which must be done, in order to conduct the cost-efficiency analysis. First of all classes of motor vehicles must be determined. According to the motor vehicle classification in this study, there are 7 classes due to the engine capacity for light duty vehicles. In the next strep the baseline model must be chosen. The baseline model is considered as a model in each class that has the least efficient among others.

Based on gathered information which is collected in appendix B, the baseline model for each class and the relative fuel economy rating and its brand are determined. Table 4.14 presents these models.

Table 4.14.The baseline model foe each class and the related FER

Class	Engine Capacity	FER Base (km/L)	FER Base (L/100km)	Model
1	below1000	16	6.25	MWM110
2	1000-1300	13.87	7.21	MWM110-1100cc
3	1300-1400	14.18	7.05	Pride Saba
4	1400-1500	11.45	8.73	Proton H back
5	1500-1600	10.01	9.99	Vanet Peykan
6	1600-1800	11.21	8.92	Peugeot 405 GLX
7	1800-2000	9.52	10.5	Vanet Mazda

In the third step the design option for each class must be determined. According to the available technologies and the collected information from car manufacturers, the design options are chosen. Table 4.15 presents the available design options (Energy, Systems et al. 2002).

Table 4.15.The available design options for light duty vehicles

NO.	Technology	Potential Fuel Efficiency Improvement (%)	Potential Average Retail Price Increase ($)
A	**Engine technologies production intent engine technologies**		
A1	Engine friction and other mechanical/hydrodynamic loss reduction	1-5	35-140
A2	Application of advance low friction lubricants	1	8 -11
A3	Multi-valve, overhead camshaft valve trains	2-5	105-140
A4	A4 Variable valve timing	2-3	35-140
A5	Variable valve lift and timing	1-2	70-210
A6	Cylinder deactivation	3-6	112-252

Continue Table 4.15.The available design options for light duty vehicles

NO.	Technology	Potential Fuel Efficiency Improvement (%)	Potential Average Retail Price Increase ($)
A7	Engine accessory improvements	1-2	84-112
A8	Engine downsizing and supercharging	5-7	350-560
C	**Transmission technologies Production-intent transmission technologies**		
C1	Continuous variable transmission (CVT)	4-8	140-350
C2	Five speed automatic transmission	2-3	70 -154
E	**Vehicle technologies Production-intent vehicle technologies**		
E1	Aerodynamic drag reduction on vehicle design	1-2	0 -140
E2	Improved rolling resistance	1-3.5	14-56

The most efficient design option with least increase of cost must be consider. Table 4.16 present the chosen option for light duty vehicles in Iran.

Table 4.16.The selected design options for light duty vehicles

No.	Design Option	FER Imp. (%)	Incremental Cost (Rials)
A1	Engine friction and other mechanical/hydrodynamic loss reduction	1 - 5	1,680,000
A2	Application of advanced, low friction lubricants	1	132,000
A7	Engine accessory improvement	1 - 2	1,344,000
E2	Improved rolling resistance	1 - 3.5	672,000

As explained before, life cycle cost and payback must be considered as cost estimating. For calculating the life cycle cost, the present worth factor (*PWF*) and purchase price (*PC*) and the annual operating cost (*OC*) must be determined. The calculation of *PWF* consider to the discount rate (r) equal to 7% and lifespan of vehicle N equal to 10 is presented as follow.

$$PWF = \frac{1}{0.07}\left[1 - \frac{1}{(1+0.07)^{10}}\right] = 7.023$$

The purchase price of each class is determined due to the information from the manufacturer. The operating cost includes the annual payment for fuel consumption and maintenance cost and the insurance cost for vehicles which is mandatory in Iran. The table 4.17 presents these values.

Table 4.17.The vehicle cost and maintenance cost for light duty vehicle in Iran

Vehicle	Approximately Vehicle cost (Rials)	Maintenance and insurance cost (Rials)
Motor vehicle with engine capacity up to 1400c.c.	80,000,000	3,705,600
Motor vehicle with engine capacity between 1400 - 1600 c.c.	130,000,000	6,006,400
Motor vehicle with engine capacity between 1600 - 2000 c.c.	180,000,000	8,307,400

The payback period for each class can be calculated based on incremental purchase price and the operating cost. The results of calculation are tabulated in the tables 4.18 to 4.24

The figures 4.3 to 4.9 also show the cost-efficiency curves for each class. In these curves, the final price of the vehicle and improved fuel economy rating due to the each design option are shown.

Table 4.18.The results of the cost estimate for combination design options class 1

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	16.00	80,000,000	12,455,600	167,475,679	0.00
A1	16.80	81,680,000	12,038,933	166,229,429	4.03
A2	16.97	81,812,000	11,956,425	165,781,973	1.60
A7	17.31	83,156,000	11,794,644	165,989,786	8.31
E2	17.91	83,828,000	11,521,102	164,740,697	2.46

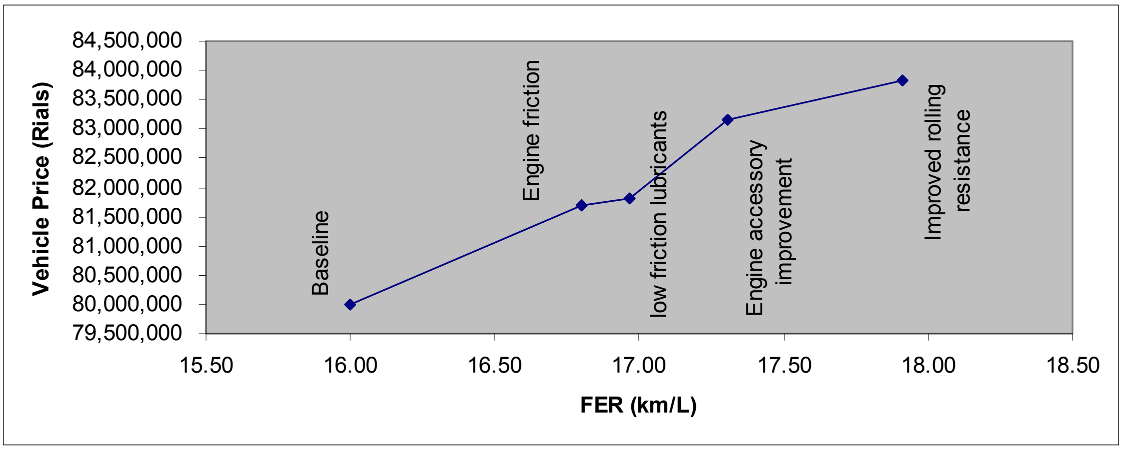


Fig.4.3 The cost-efficiency curve for class 1

Table 4.19.The results of the cost estimate for combination design options class 2

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	13.87	80,000,000	13,799,327	176,912,677	0.00
A1	14.56	81,680,000	13,318,674	175,217,046	3.50
A2	14.71	81,812,000	13,223,495	174,680,604	1.39
A7	15.00	83,156,000	13,036,869	174,713,934	7.20
E2	15.53	83,828,000	12,721,319	173,169,825	2.13

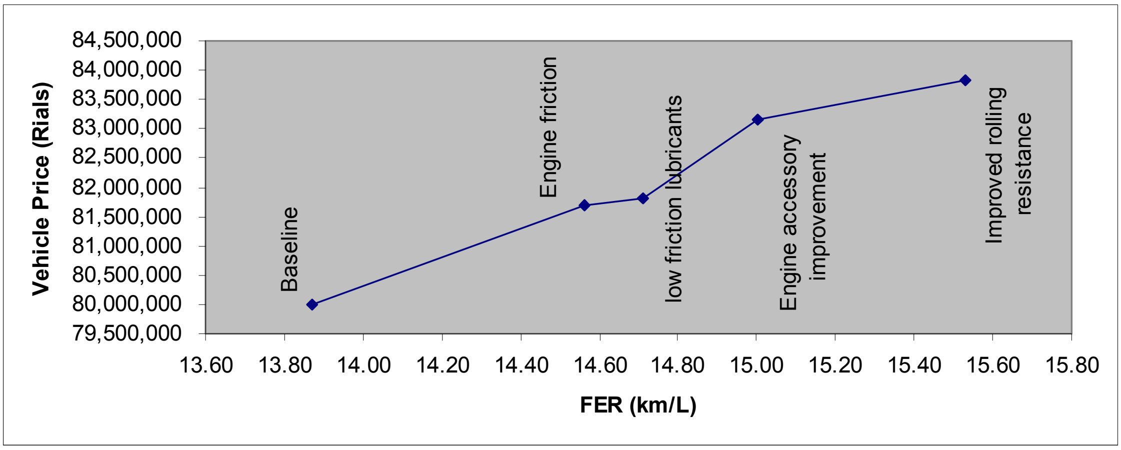


Fig.4.4 The cost-efficiency curve for class 2

Table 4.20.The results of the cost estimate for combination design options class 3

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	14.18	80,000,000	13,578,661	175,362,934	0.00
A1	14.89	81,680,000	13,108,515	173,741,100	3.57
A2	15.04	81,812,000	13,015,417	173,219,272	1.42
A7	15.34	83,156,000	12,832,871	173,281,255	7.36
E2	15.88	83,828,000	12,524,220	171,785,594	2.18

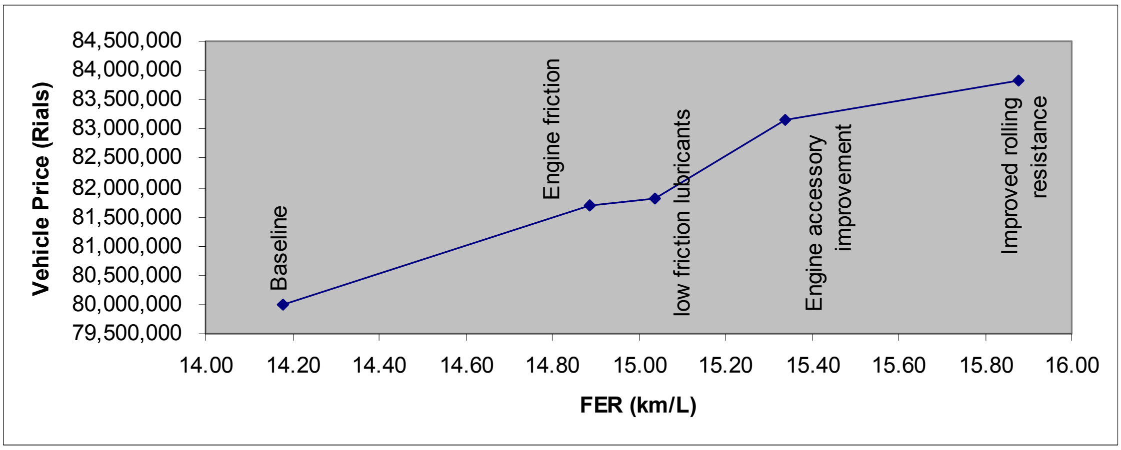


Fig.4.5 The cost-efficiency curve for class 3

Table 4.21.The results of the cost estimate for combination design options class 4

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	11.45	130,000,000	18,233,474	258,053,690	0.00
A1	12.02	131,680,000	17,651,233	255,644,607	2.89
A2	12.14	131,812,000	17,535,937	254,966,887	1.14
A7	12.39	133,156,000	17,309,868	254,723,202	5.95
E2	12.82	133,828,000	16,927,625	252,710,710	1.76

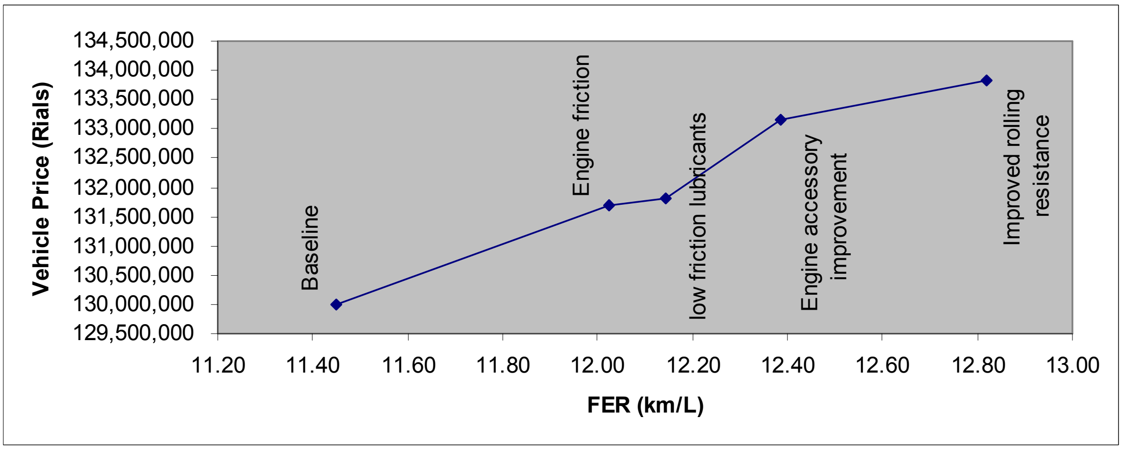


Fig.4.6 The cost-efficiency curve for class 4

Table 4.22.The results of the cost estimate for combination design options class 5

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	10.01	130,000,000	19,992,414	270,406,723	0.00
A1	10.51	131,680,000	19,326,413	267,409,401	2.52
A2	10.62	131,812,000	19,194,532	266,615,198	1.00
A7	10.83	133,156,000	18,935,941	266,143,115	5.20
E2	11.21	133,828,000	18,498,710	263,744,443	1.54

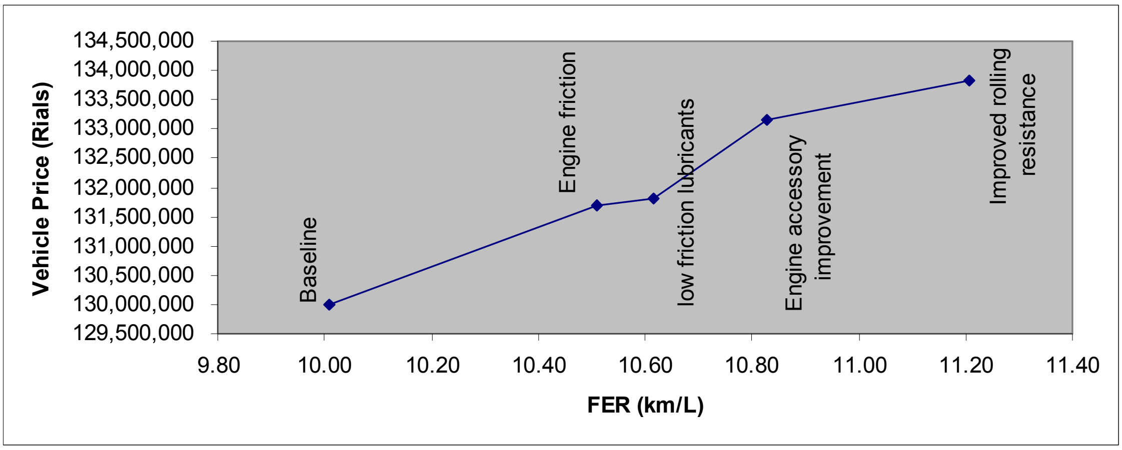


Fig.4.7 The cost-efficiency curve for class 5

Table 4.23.The results of the cost estimate for combination design options class 6

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	11.21	180,000,000	20,796,249	326,052,058	0.00
A1	11.77	181,680,000	20,201,542	323,555,430	2.82
A2	11.89	181,812,000	20,083,778	322,860,375	1.12
A7	12.13	183,156,000	19,852,869	322,582,699	5.82
E2	12.55	183,828,000	19,462,442	320,512,734	1.72

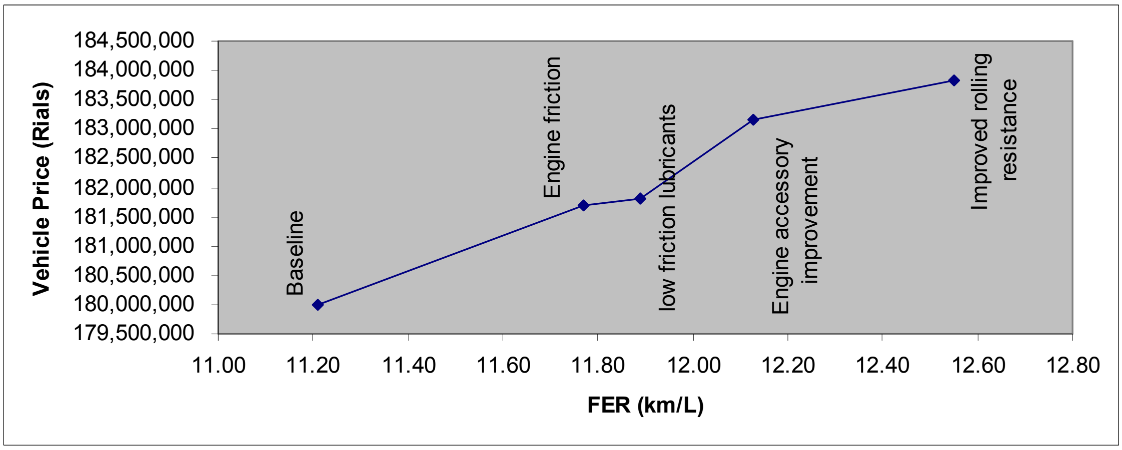


Fig.4.8 The cost-efficiency curve for class 6

Table 4.24.The results of the cost estimate for combination design options class 7

Design Option	FER Imp.	Price (Rial)	OC(Rial)	LCC(Rial)	PAY(Year)
0	9.52	180,000,000	23,013,282	341,622,282	0.00
A1	10.00	181,680,000	22,313,002	338,384,215	2.40
A2	10.10	181,812,000	22,174,333	337,542,340	0.95
A7	10.30	183,156,000	21,902,432	336,976,782	4.94
E2	10.66	183,828,000	21,442,697	334,420,060	1.46

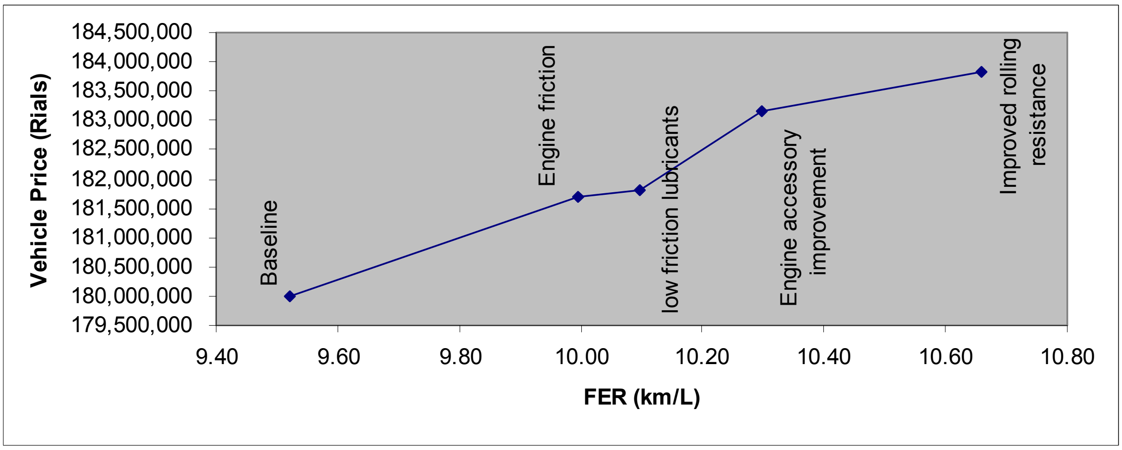


Fig.4.9 The cost-efficiency curve for class 7

4.5 Prediction of the market transformation

The changes of the average fuel economy rating of all available motor vehicles in the market are known as market transformation. The average fuel economy rating (FER_{ave}) is possible to be changed in two times due to the implementing the fuel economy standards and labels. First there is the present FER_{ave} which is before implementing the program, and after implementing the fuel economy standards it will change to the average standard fuel economy rating (FER_{SAF}). In the second step after implementing the fuel economy label the FER_{SAF} will change to the label average fuel economy rating. For calculating these parameters the data for 247 models of available motor vehicles in Iran is collected. The figure 4.10 shows the different *FER* of each model due to the engine capacity. The average *FER* of all these models is equal to 11.3 in year 2008. The calculation is given as follow. It must be consider that the standards improvement is selected 5%.

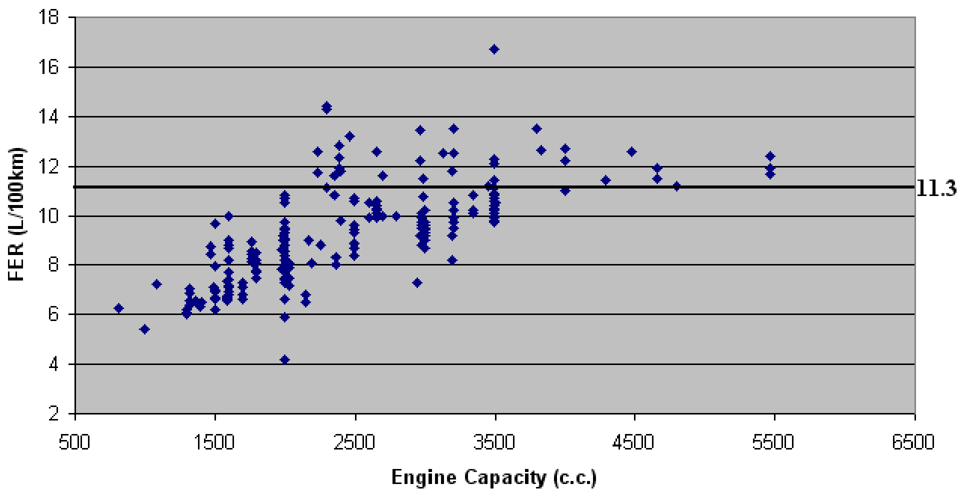


Fig.4.10 Different *FER* 247 models due to the engine capacity

The present average fuel economy rating:

$$FER_{PAF} = 11.3 \times (1 + 0.0418)^{(2013-2008)} = 13.9 \qquad (4.3)$$

The standards average fuel economy rating:

$$FER_{SAF} = 16.6 \tag{4.4}$$

The labels average fuel economy rating:

$$FER_{SAF} = 16.6 \times \left(1 + \frac{0.045}{7}\right) = 17.7 \tag{4.5}$$

The figure 4.11 shows the schematic of these changes and the determined value of each step for light duty vehicles in Iran.

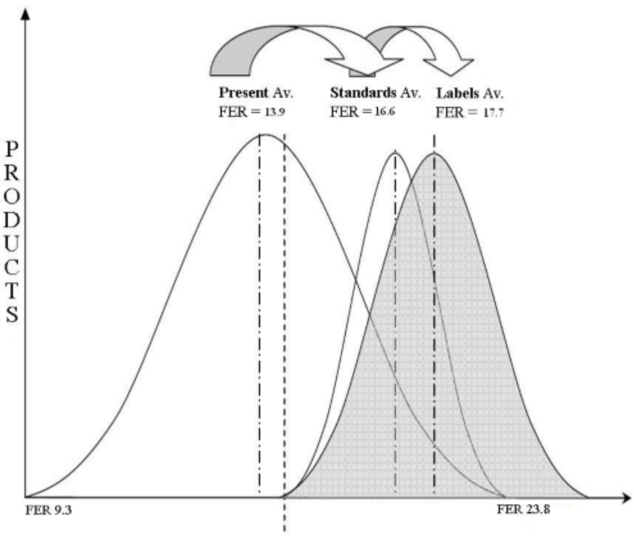


Fig.4.11 The market transformation due to implementing fuel economy standards and labels

4.6 Prediction of potential savings and environmental impact by implementing the fuel economy standards and label

The impacts of implementing the fuel economy standards and labels can be analyzed by using economic/engineering approach. According to the *Mahlia's* theory this analysis gives the accurate results (Mahlia, Masjuki et al. 2002). In this section the effects of program on the fuel saving, economic and environment of Iran are discussed.

In order to calculate the impacts due to the fuel economy standards and labels for light duty vehicle in Iran some essential data is required. These necessary data are tabulated in table 4.25.

Table 4.25.The initial required data

Description	Values
IC (Rial)	25,000
Year standards enacted	2013
Discount rate	7% (in year 2006)
Life span	10 years
Baseline fuel consumption	2649.6 lit/year
Estimated fuel price in year of implementation	7,000 Rials (1.75 RM)
Standards fuel consumption	2517.12 lit/year
Annual mileage	20,000 km
Annual fuel economy improvement (AFI)	4.18%

4.6.1 The impacts of the fuel economy standards

4.6.1.1 Potential fuel savings

In order to calculate the potential fuel saving due to the implementing fuel economy standards, it is required to calculate some other parameters. Some important factors are the unit fuel saving, shipment, and applicable stock. The samples of calculations are presented in appendix B. Finally, the potential fuel saving can be calculated by using equation 5.1. The results of fuel saving due to the standards are tabulated in table 4.26.

Table 4.26.The results of fuel saving due to the fuel economy standards

Year	Sh	AS	SF	UFSi	FS
2013	6,122,888	6,122,888	1.00	132.48	811,160,446
2014	6,919,873	13,042,761	0.80	105.98	1,105,859,518
2015	7,879,085	20,921,846	0.60	79.49	997,821,717
2016	8,881,504	29,803,350	0.41	54.32	663,717,466
2017	9,904,290	39,707,640	0.21	27.82	231,986,715
2018	10,857,995	50,565,635	0.01	1.32	669,894

The total fuel saving by implementing fuel economy standards for years during 2013 to 2018 is equal to 3,811,215,757 liters.

4.6.1.2 Potential economic savings

The bill saving, net saving and cumulative present value are the most important of economic effects due to the fuel economy standards implementation. According to the results obtained before and the equations 5.9-5.13, these three economic parameters can be calculated. Table 4.27 presents the achieved results.

Table 4.27.The results of potential economic savings due to the fuel economy standards

Year	BS(Rial)	ANS(Rial)	PV(Rial)
2013	5,678,123,124,171	2,790,848,157,750	1,737,999,969,878
2014	7,741,016,627,409	3,804,778,713,189	2,214,415,851,932
2015	6,984,752,020,004	3,433,067,913,654	1,867,361,478,819
2016	4,646,022,263,615	2,283,561,379,654	1,160,846,810,893
2017	1,623,907,005,658	798,164,776,633	379,202,335,709
2018	4,689,256,138	2,304,811,215	1,023,363,743

The total bill saving is equal to 26,678,510,296,996 Rials due to the implementation of fuel economy standards during the years 2013 to 2018.

4.6.1.3 Potential environmental impact

The emission reduction due to the fuel economy standards implementation can be obtained according to the fuel saving and emission factor. Table 4.28 present the emission factors of the petroleum which is consumed by light duty vehicles (Mirzaee, Parsafare et al. 2008).

Table 4.28.The emission factors

Description	Value (kg/1000lit)	Value (kg/lit)
CO_2	1928.61	1.92861
CO	66.696	0.066696
NO_X	31.63	0.03163
CH	64.81	0.06481
SPM	1.336	0.001336

According to the amount of fuel saving the results of emission reduction are tabulated in Table 4.29 for each year.

Table 4.29.The emission reduction due to the fuel economy standards

Year	Fuel Saving (lit)	CO_2(ton)	CO	NO_X	CH	SPM
2013	811,160,446	1,564,412	54,101,157	25,657,005	52,571,309	1,083,710
2014	1,105,859,518	2,132,772	73,756,406	34,978,337	71,670,755	1,477,428
2015	997,821,717	1,924,409	66,550,717	31,561,101	64,668,825	1,333,090
2016	663,717,466	1,280,052	44,267,300	20,993,383	43,015,529	886,727
2017	231,986,715	447,412	15,472,586	7,337,740	15,035,059	309,934
2018	669,894	1,292	44,679	21,189	43,416	895
Total	3,811,215,757	7,350,349	254,192,846	120,548,754	247,004,893	5,091,784

By implementing the fuel economy standards the total emission reduction for CO_2 is 7,350,349 ton and the amount of 254,192,846 kg and 120,548,754 kg due to the CO, NO_X emission will reduce, respectively.

4.6.2 The impacts of the fuel economy labels

The same as impacts of fuel economy standards the fuel economy labels has effect on fuel saving, economic saving and emission reduction. Based on the possible selected grades of labels by consumers, these effects can be predicted (Mahlia, Masjuki et al. 2002).

4.6.2.1 Potential fuel savings (label)

In order to evaluate the potential fuel saving due to the implementing fuel economy labels, it is required to calculate some other parameters. The most important issue that must be considered is the baseline fuel consumption for fuel economy labels. The standard fuel consumption is selected as a baseline for fuel economy labels. Since this baseline is static the scaling factor can be removed from the equations. Therefore due to the equation 3.31 and 3.24 the results of fuel saving due to the fuel economy labels are represented in table 4.30.

Table 4.30.The results of fuel saving due to the fuel economy labels

Year	Sh	AS	UFS	FS
2013	6,122,888	6,122,888	125.9	770,602,424
2014	6,919,873	13,042,761	125.9	1,641,510,222
2015	7,879,085	20,921,846	125.9	2,633,140,642
2016	8,881,504	29,803,350	125.9	3,750,931,546
2017	9,904,290	39,707,640	125.9	4,997,446,244
2018	10,857,995	50,565,635	125.9	6,363,990,473

The total fuel saving by implementing fuel economy standards for years during 2013 to 2018 is equal to 3,811,215,757 liters.

4.6.2.2 Potential economic savings (labels)

The same as fuel economy standards, the bill saving, net saving and cumulative present value are the most important of economic effects due to the fuel economy labels implementation. According to the results obtained before and the equations 3.24 and 3.31, these three economic parameters can be calculated that the results of the calculations are tabulated in table 4.31.

Table 4.31.The results of potential economic savings due to the fuel economy labels

Year	BS(Rial)	ANS(Rial)	PV(Rial)
2013	5,394,216,967,962	2,651,305,749,862	1,651,099,971,384
2014	11,490,571,556,311	5,647,718,402,391	3,287,023,530,211
2015	18,431,984,497,232	9,059,484,772,142	4,927,759,457,995
2016	26,256,520,823,526	12,905,314,162,230	6,560,407,319,146
2017	34,982,123,704,652	17,194,025,800,480	8,168,757,798,711
2018	44,547,933,313,949	21,895,706,539,288	9,721,955,559,469

The total bill saving is equal to 141,103,350,863,632 Rials due to the implementation of fuel economy labels during the years 2013 to 2018.

4.6.2.3 Potential environmental impact (labels)

The emission reduction due to the fuel economy standards implementation can be obtained according to the fuel saving and emission factor. Based on emission factors in table 4.27 and the amount of fuel saving the results of emission reduction are tabulated in Table 4.32 for each year.

Table 4.32.The results of potential economic savings due to the fuel economy labels

Year	Fuel Saving	CO_2(ton)	CO	NO_X	CH	SPM
2013	770,602,424	1,486,192	51,396,099	24,374,155	49,942,743	1,029,525
2014	1,641,510,222	3,165,833	109,482,166	51,920,968	106,386,278	2,193,058
2015	2,633,140,642	5,078,301	175,619,948	83,286,239	170,653,845	3,517,876
2016	3,750,931,546	7,234,084	250,172,130	118,641,965	243,097,874	5,011,245
2017	4,997,446,244	9,638,125	333,309,675	158,069,225	323,884,491	6,676,588
2018	6,363,990,473	12,273,656	424,452,709	201,293,019	412,450,223	8,502,291
Total	20,157,621,552	38,876,191	1,344,432,727	637,585,570	1,306,415,453	26,930,582

By implementing the fuel economy labels the total emission reduction for CO_2 is 38,876,191ton and the amount of 1,344,432,727 kg and 637,585,570kg due to the CO, NO_X emission will reduce, respectively.

4.6.3 The impacts of the fuel economy standards and labels

In this study it is assumed that the fuel economy standards and the fuel economy labels will be implemented at the same time. Therefore, the table 4.33 presents the total fuel saving for both programs in each year.

Table 4.33.The results of fuel saving due to the fuel economy standards and labels

Year	Fuel Saving (STD)	Fuel Saving (Label)	Total Fuel Saving
2013	811,160,446	770,602,424	1,581,762,870
2014	1,105,859,518	1,641,510,222	2,747,369,741
2015	997,821,717	2,633,140,642	3,630,962,360
2016	663,717,466	3,750,931,546	4,414,649,012
2017	231,986,715	4,997,446,244	5,229,432,959
2018	669,894	6,363,990,473	6,364,660,367

The total amount of fuel saving due to implementing the fuel economy standards and labels is around 23,968,837,309 liters after 5 years.

In addition the total amounts of the economic effects and emissions reduction by implementing the fuel economy standards and labels during year 2013 to 2018 are presented in the tables 4.34 and 4.35, respectively.

Table 4.34.The results of economic saving due to the fuel economy standards and labels

	Fuel Saving	BS(Rial)	ANS(Rial)	PV(Rial)
STD	3,811,215,757	26,678,510,296,996	13,112,725,752,094	7,360,849,810,973
Label	20,157,621,552	141,103,350,863,632	69,353,555,426,392	34,317,003,636,915
Total	23,968,837,309	167,781,861,160,628	82,466,281,178,486	41,677,853,447,888

Table 4.35.The results of emission reduction due to the fuel economy standards and labels

	CO_2(ton)	CO	NO_X	CH	SPM
STD	7,350,349	254,192,846	120,548,754	247,004,893	5,091,784
Label	38,876,191	1,344,432,727	637,585,570	1,306,415,453	26,930,582
Total	46,226,539	1,598,625,573	758,134,324	1,553,420,346	32,022,367

CHAPTER 5
CONCLUSION & RECOMMENDATION

5.1 Conclusions

The important of the fuel economy standard and label for light duty vehicles in Iran has been discussed and analyzed in this research. Therefore, it is suggested that the policy makers of this country put this program into practice to help decrease the fuel consumption in the transportation section. Some organizations are responsible for this issue such as Ministry of Petroleum, Iranian Energy Commission, Institute of International Energy Studies, Economic Planning Unit and Department of the optimization fuel consumption are the associations and institutions who should be responsible for this issue.

In order to establish the fuel economy standard and label, the test procedure is the fundamental of calculation and decision. The chosen test procedure for light duty vehicles makes a guideline to measure the fuel consumption. Due to the condition of Iran such as trade policies, climate and dominant traffic situation, the European driving test cycle (NEDC) is selected.

A suitable label, after setting the standards is selected. In order to achieve an effective label and understandable, the common type of label which is bar ranking is developed as fuel economy label.

Based on the proposed fuel economy standards and label in this research, it is expected that the average fuel economy rating of light duty vehicles in Iran must improve from 13.9 to 16.6 due to the implementing the fuel economy standards during years 2013 to 2018. By implementation of fuel economy label the *FER* should improve to 17.7 in this period.

In order to predict the impacts of this program in Iran, the economic/engineering analysis is conducted. According to the calculation it is estimated that around 3,811,215,757 liters of fuel will be saved by implementing the standards and by executing the fuel economy labels the fuel saving will be approximately 20,157,621,552 liters, that it is expected around 23,968,837,309 liters total of fuel saving after the 5 years of implementation of the program. This amount of fuel saving causes the bill saving around of 167,781,861,160,628 Rials, totally. The emission reduction due to the implementation of fuel economy standards and labels is predicted. In total, it is obtained that around 46,226,539 ton of CO_2 emission will reduce. The emission reduction of CO and NO_X is calculated around 1,598,625,573 kg and 758,134,324 kg respectively.

According to the obtained results, it is realized that after few years the effect of fuel economy standards will decrease. The most effective duration for proposed fuel economy standards in this research is during the 2013 to 2018.

5.2 Recommendations

To obtain best possible effect of the execution of the fuel economy and label program for light duty vehicle in this country a number of steps should be considered. It is found that the accurate information is required for implementing the fuel economy standards and labels. Therefore, in order to upgrade the programs it is necessary to collect the data. For this reason the government must set up a framework to constantly gather information from vehicle producers and traders selling their cars in the Iranian market.

In order to accomplish the fuel economy standard and label plan with exact results it is required to establish an independent laboratory for testing. The facility should contain ways to predict cars maintenance, traffic behavior and the type of roads in Iran.

The fuel economy standards and labels can be implemented separately. In order to support the local companies it is better to implement the fuel economy standards. This can be conducted by agreement between government and car manufacturers. After obtaining the desired fuel economy rating the fuel economy label can be a mandatory program in order to achieve more improvement of the FER_{avg}.

It must keep in mind that the program is effective for a certain period of years. It should plan to prepare the new set of fuel economy standards and labels. The government or other organizations are responsible about it.

APPENDIX A: RELATED PUBLICATIONS

1. Mohammadnejad, M., M. Ghazvini, et al. (2011). "A review on energy scenario and sustainable energy in Iran." Renewable and Sustainable Energy Reviews.

APPENDIX B:
SURVEY DATA

B.1. Fuel consumption of different engine capacity

In the following table the collected data due to the fuel consumption of different engine capacity in highway and city are represented. *(liters/100km)*

Engine Capacity	Fuel Consumption (Lit/100km)	
	City	Highway
800	7.9	5.1
812	10	4.2
1323	9.55	5.3
1360	8.9	5
1360	9.4	5.4
1360	9.4	5.5
1400	9.4	5.4
1495	9	5.7
1500	9.19	7.97
1500	9.3	5.2
1500	10	6.6
1587	6.6	6.6
1587	8.6	5.1
1587	9.9	5.5
1598	8.8	5.4
1598	9	5.4
1598	9	5.6
1598	9.6	6.3
1598	9.8	6.3
1598	10.1	5.8
1598	10.4	5.7
1598	11.5	7
1598	12.54	8.53
1600	8.5	6.7
1645	9.2	5.8
1761	5.8	5.8
1761	6.8	9.2
1761	8.98	7.4
1761	11.37	6.27
1761	12.8	6.76
1761	12.8	7.4
1761	13.19	6.77
1975	9.5	6.8
2000	11.3	6.1
2237	14.375	11.5
2972	15.625	12.5
2295	16	9.4
2295	17.8	11
2389	9.011	9
2389	11	8.08
2389	15.63	12.5
2400	12	8.75
2899	16	8
3500	13.5	10.5

B.2. Fuel consumption of different models of light duty vehicles

The fuel consumption of common vehicles in Iran are collected. These data are tabulated in the following table.

Model of Vehicle	Engine Capacity	Fuel consumption (liters/100km)	Fuel consumption (km/liter)
MWM110	812	6.25	16.00
Toyota Yarise	998	5.4	18.52
MWM110-1100CC	1083	7.21	13.87
Toyota Yarise	1298	6	16.67
Toyota Corllia 1.3	1300	6.1	16.39
Toyota Corllia 1.3(A)	1300	6.2	16.13
Pride Saba Sazhm	1323	7.05	14.18
Pride Saba Zimens	1323	6.89	14.51
Pride Nasim Zimens	1323	6.55	15.27
Pride 141 Zimens	1323	6.36	15.72
Peugeot 206 Tip 2	1360	6.53	15.31
Peugeot 206 SD	1360	6.55	15.27
Peugeot 206 SD 2	1360	6.55	15.27
Kia Roa	1399	6.3	15.87
Fiat Siena 1.4	1400	6.5	15.38
Proton H Back Automatic	1468	8.73	11.45
Proton Sedan Automatic	1468	8.47	11.81
Hyundai Verna	1495	7.14	14.01
M.Benz A150 Coupe	1498	6.2	16.13
M.Benz A150 Coupe Automatic	1498	6.6	15.15
M.Benz A150 Sedan	1498	6.7	14.93
M.Benz A150 Sedan Automatic	1498	7	14.29
Proton Sedan	1500	9.67	10.34
Proton H Back	1500	7.95	12.58
Rio	1500	6.94	14.41
Peugeot 206 Tip 5	1587	6.72	14.88
Peugeot 206 Tip 6	1587	7.35	13.61
Peugeot 206 SD-1600cc	1587	6.55	15.27
Peugeot 206 SD 2-1600cc	1587	6.61	15.13
Peugeot 405	1597	8.81	11.35
Vanet Peykan	1598	9.995	10.01
Peugeot Roa	1598	8.67	11.53
Peugeot Roa 2	1598	8.67	11.53
L90	1598	6.9	14.49
L90 2	1598	6.9	14.49
Mazda GLX323	1598	7.13	14.03
Mazda GLX323 Automatic	1598	7.39	13.53
Cherry A15	1600	8.97	11.15
Hyundai Verna	1600	6.82	14.66
Hyundai Verna Automatic	1600	8.18	12.22
Proton Impian	1584	6.7	14.93
Proton Gent2	1597	7.2	13.89
Renault Logane	1598	6.92	14.45
Renault Megane 1.6	1598	6.9	14.49

Renault Megane 1.6 (A)	1598	7.7	12.99
Peugeot Pars	1761	8.43	11.86
Peugeot Pars 2	1761	8.43	11.86
Peugeot Pars ELX	1761	8.17	12.24
Samand	1761	8.59	11.64
Samand Limosin sarir	1761	8.29	12.06
Samand 2	1761	8.59	11.64
Samand LX	1761	8.6	11.63
Peugeot 405 GLX	1761	8.92	11.21
Peugeot 405 2	1761	8.92	11.21
Zantia 1800cc	1761	8.15	12.27
Volkswagen Gol	1781	8.05	12.42
M.Benz A170 Coupe	1699	6.6	15.15
M.Benz A170 Coupe Automatic	1699	6.6	15.15
M.Benz A170 Sedan	1699	6.8	14.71
M.Benz A170 Sedan Automatic	1699	7.1	14.08
M.Benz B170	1699	7.1	14.08
M.Benz B170 Automatic	1699	7.3	13.70
M.Benz C180 Coupe	1796	7.8	12.82
M.Benz C180 Automatic	1796	7.8	12.82
M.Benz C180 K Automatic	1796	8.5	11.76
M.Benz C180 Estate	1796	8.5	11.76
M.Benz C180 Coupe (A)	1796	8.1	12.35
M.Benz C200 K	1796	7.8	12.82
M.Benz C200 K Automatic	1796	8.1	12.35
M.Benz C200 Coupe (A)	1796	8.5	11.76
Toyota Corllia 1.8 (multi 5)	1796	7.5	13.33
Toyota Corllia 1.8	1796	7.7	12.99
M.Benz E200	1798	8.2	12.20
M.Benz E200 (A)	1798	8.5	11.76
Hyundai Avante	1975	7.81	12.80
Hyundai Avante Automatic	1975	8.63	11.59
Zantia 2000cc	1998	9.03	11.07
Vanet Mazda 1	1998	10.5	9.52
Vanet Mazda 2	1998	9.5	10.53
Suzuki	1995	9.4	10.64
Suzuki Automatic	1995	9.4	10.64
Toyota Raw 3door	1988	8.7	11.49
Toyota Raw 3door (A)	1988	9.2	10.87
Toyota Raw 5door	1988	8.6	11.63
Toyota Raw 5door (A)	1988	9	11.11
BMW 118i	1995	5.9	16.95
BMW 320i Sedan	1995	8.2	12.20
BMW 320i Saloon	1995	7.4	13.51
BMW 318i	1995	7.3	13.70
BMW 120i	1995	7.9	12.66
BMW 120i Cabriolet	1995	6.6	15.15
Cttron C5	1997	8	12.50
Cttron C5 (A)	1997	8.6	11.63
Fujian Delica pride DN6492	1997	10.7	9.35
Honda Acord	1998	10.8	9.26
Honda Civic	1998	9.73	10.28
Renault Megane2	1998	8	12.50
Renault Megane2 (A)	1998	8.4	11.90

Mazda 6	1999	8.8	11.36
Hyundai Sonata2	2000	8	12.50
Hyundai Sonata2 (A)	2000	8.4	11.90
KIA Cerato	2000	7.5	13.33
KIA Cerato (A)	2000	7.7	12.99
KIA Sportage2	2000	8.2	12.20
Toyota Hilux2	2000	8.2	12.20
Volkswagen Van	2000	9	11.11
Volkswagen Van 2	2000	8.4	11.90
Volkswagen Van 2 Normal	2000	4.2	23.81
Volkswagen Truck 2	2000	9.3	10.75
M.Benz A200 Coupe	2034	7.2	13.89
M.Benz A200 Turbo Coupe	2034	7.9	12.66
M.Benz B200	2034	7.5	13.33
M.Benz B200 (A)	2034	7.5	13.33
M.Benz B200 Turbo	2034	7.9	12.66
M.Benz B200 Turbo (A)	2034	8.1	12.35
M.Benz C200 Coupe	2148	6.5	15.38
M.Benz C200 State	2148	6.8	14.71
BMW 520i Swdan	2171	9	11.11
Opel vectra	2193	8.1	12.35
Van Naron	2237	11.71	8.54
Van Naron 2	2237	12.61	7.93
Van Benz	2295	14.31	6.99
Nissan Pickup	2389	12.36	8.09
Nissan Pickup 2	2389	12.84	7.79
Van Karvan	2389	11.89	8.41
Mazda 6	2261	8.8	11.36
M.Benz Sprinter 314KA	2295	14.42	6.93
Shac Istana 6530	2295	11.1	9.01
Fujian Delica 6490M	2350	11.6	8.62
Hyundai Acord	2354	10.8	9.26
Hyundai Sonata 2.3	2359	8	12.50
Hyundai Sonata 2.3(A)	2359	8.3	12.05
Suzuki Grand Vitara	2393	11.8	8.47
Toyota Camry 2.4	2400	9.8	10.20
Van Dili	2798	10	10.00
Pazhan GLV3000	2972	12.21	8.19
Pazhan GLD3000	2972	13.41	7.46
Maxima	2988	10.76	9.29
Maxima Automatic	2988	11.48	8.71
Russion LTD Gazelle22132	2463	13.2	7.58
BMW 525i Sedan	2494	8.7	11.49
M.Benz C230	2496	9.3	10.75
M.Benz C230 Automatic	2496	9.3	10.75
BMW 325i Cabriolet	2497	8.9	11.24
BMW 325i Coupe	2497	8.4	11.90
BMW 325i Sedan	2497	8.4	11.90
M.Benz C230 Coupe	2497	10.6	9.43
M.Benz C230 Coupe Automatic	2497	10.7	9.35
M.Benz E240	2597	10.5	9.52
M.Benz E240 (A)	2597	9.9	10.10
Hyundai Canate 2WD	2656	10.1	9.90
Hyundai Canate 2WD (A)	2656	10.2	9.80
Hyundai Canate 4WD	2656	10.4	9.62
Hyundai Canate 4WD (A)	2656	10.6	9.43

Hyundai Coupe	2656	9.9	10.10
Hyundai Coupe (A)	2656	10.3	9.71
Hyundai Tacson (A)	2656	10	10.00
Hyundai Terajet (A)	2656	12.59	7.94
Toyota Hiace	2694	11.6	8.62
KIA Sportage2.7 (A)	2700	10	10.00
Peugeot 607	2946	7.3	13.70
Audi A4	2967	9.2	10.87
BMW 325i Saloon	2979	9.6	10.42
BMW 325i Convertible	2979	9.9	10.10
BMW 325i Cuope	2979	9.5	10.53
BMW 530i Sedan	2979	8.8	11.36
BMW 530xi Sedan	2979	9.7	10.31
BMW 630i Sedan	2979	10.1	9.90
BMW 730Li Sedan	2979	10.1	9.90
BMW 330i Cabriolet	2996	9.2	10.87
BMW 330i Coupe	2996	8.7	11.49
BMW 330i Sedan	2996	8.7	11.49
BMW 630i Cabriolet	2996	9.6	10.42
BMW 630i Coupe	2996	9	11.11
BMW X3 SUV	2996	9.5	10.53
M.Benz C280	2996	9.4	10.64
M.Benz C280 4Matic Automatic	2996	9.6	10.42
M.Benz C280 (A)	2996	9.4	10.64
M.Benz C280 Automatic	2996	9.4	10.64
M.Benz E230	2496	9.4	10.64
M.Benz E230 (A)	2496	9.6	10.42
M.Benz CLK280 Cabriolet	2996	9.5	10.53
M.Benz CLK280 Cabriolet Automatic	2996	9.6	10.42
M.Benz CLK280 Coupe	2996	9.2	10.87
M.Benz CLK280 Coupe Automatic	2996	9.5	10.53
M.Benz E280 (A)4Matic Automatic	2996	10.2	9.80
M.Benz SLK280	2996	9.7	10.31
M.Benz SLK280 (A)	2996	9.5	10.53
M.Benz E280	2997	9.3	10.75
M.Benz E280 (A)	2997	9.4	10.64
Pajero	3497	16.73	5.98
Benz E350	3498	11.44	8.74
Pajero Automatic	3828	12.64	7.91
Audi A6	3123	12.55	7.97
Audi TT	3189	8.2	12.20
Suzuki Grand Vitara	3195	11.8	8.47
Audi A4	3197	9.2	10.87
M.Benz CLK320 (A)	3199	10.2	9.80
M.Benz Viano 3 (A)	3199	12.5	8.00
Mitubishi Pajero (A)	3200	13.5	7.41
Volkswagen Van 3.2 H	3200	10.5	9.52
Volkswagen Van 3.2 H (A)	3200	10.2	9.80
Volkswagen Van 3.2 M	3200	9.9	10.10
Volkswagen Van 3.2 M (A)	3200	9.7	10.31
Volkswagen Van 3.2 N	3200	9.7	10.31
Volkswagen Van 3.2 N (A)	3200	9.5	10.53
KIA Sorento	3340	10.8	9.26

Hyundai Azera (A)	3342	10.2	9.80
Hyundai Sonata 3.3 (A)	3342	10.1	9.90
Lexus LS 460	3456	11.2	8.93
Lexus RX 350	3456	11.2	8.93
M.Benz C350	3498	9.8	10.20
M.Benz C350 Sport Coupe	3498	10.8	9.26
M.Benz C350 Sport Coupe Automatic	3498	11.1	9.01
M.Benz C350 Automatic	3498	10	10.00
M.Benz CLK 350	3498	10.2	9.80
M.Benz C350	3498	9.8	10.20
M.Benz CLS350 Automatic	3498	10.6	9.43
M.Benz CLS350 (A)	3498	10.1	9.90
M.Benz E350	3498	9.7	10.31
M.Benz E350 4Matic	3498	10.4	9.62
M.Benz E350 4Matic Automatic	3498	10.7	9.35
M.Benz S350	3498	12.1	8.26
M.Benz S350 Automatic	3498	10.3	9.71
M.Benz S350 4Matic Automatic	3498	10.8	9.26
M.Benz S350 4Matic L Automatic	3498	10.9	9.17
M.Benz S350 L Automatic	3498	10.3	9.71
M.Benz SL350	3498	10.3	9.71
M.Benz SL350 Automatic	3498	9.9	10.10
M.Benz SLK350	3498	10.6	9.43
M.Benz SLK350 Automatic	3498	10.1	9.90
M.Benz S450 L (A)	4663	11.5	8.70
M.Benz S450 4Matic L (A)	4663	11.9	8.40
M.Benz S500	5461	11.7	8.55
M.Benz S500 (A)	5461	11.9	8.40
M.Benz S500 4Matic (A)	5461	12.4	8.06
Nissan Murano	3498	12.3	8.13
Lexus ES 350 (A)	3500	10.5	9.52
Mitubishi Pajero (A)	3800	13.5	7.41
BMW 540i Sedan	4000	11	9.09
BMW 740Li Sedan	4800	11.2	8.93
Toyota Fortuner 4	4000	12.7	7.87
Toyota Land Cruser 200 (A)	4000	12.2	8.20
Toyota Prado 4 (A)	4000	12.7	7.87
Lexus GS430 (A)	4293	11.4	8.77
Toyota Land Cruser 4500	4477	12.6	7.94

APPENDIX C:
PREDICTED DATA, ANNUAL FUEL ECONOMY IMPROVEMENT AND BASELINE FUEL CONSUMPTION

C.1. Prediction of fuel consumption of light duty vehicle and the number of motor-vehicles

By using a polynomial curve fitting method the data for Motor Vehicle Fuel Consumption is predicted. According to the data tabulated in Table 4.1 the following mathematical equation can be used for prediction:

$y = 0.4418x^2 + 1090.3x + 9845.4 \quad R^2 = 0.9348$

Also the number of light duty vehicles can be predicted based on the data tabulated n in Table 4.1, and using a polynomial curve fitting method. The following mathematical equation is determined for perdition:

$y = 53603x^2 + 40978x + 3E+06 \quad R^2 = 0.9981$

The predicted number and fuel consumption of motor vehicles in Iran from year 2009 until the year 2018 using the polynomials are shown below. The type of equivalency in energy data is given by million barrels oil equivalent (Mboe). One boe is equal to 0.1461736 ton oil equivalent (toe) which has net calorific value of 10 Gcal. In this study based on the standards tables the conversion factor is considered 1 toe =10 Gcal = 41.868 GJ. Consider to this that 6.1 GJ is equivalent to 158.98703 liters, therefore, 1 boe = 169.96 liter (UN 1991; IEA 2002; EIA 2004).

Year	Unit Vehicle	Motor Vehicle Fuel Consumption (Million liters)
2009	9,936,721	21,892.16
2010	11,210,568	22,992.62
2011	12,591,621	24,093.96
2012	14,079,880	25,196.19
2013	15,675,345	26,299.31
2014	17,378,016	27,403.30
2015	19,187,893	28,508.18
2016	21,104,976	29,613.94
2017	23,129,265	30,720.59
2018	25,260,760	31,828.12

C.2. Fuel economy rating and annual fuel economy improvement

By using equations 3.3 and 3.4, the fuel economy rating and annual fuel economy improvement are calculated respectively and the results are represented in following table.

Year	FER	AFI (%)
1998	5.9088	-
1999	5.7728	-2.350
2000	5.9131	2.370
2001	5.8321	-1.388
2002	5.9071	1.270
2003	6.0774	2.801
2004	6.3368	4.090
2005	6.8459	7.436
2006	7.1119	3.740
2007	7.3317	2.990
2008	9.2634	20.850
Average		4.18%

C.3. Baseline fuel consumption calculation

The equation 3.11 is used to calculate the baseline fuel consumption for the year 2008:

$$BFC_{2008} = \frac{18,840,775,000}{8,726,500} \cong 2,159 \text{ liters/year}$$

The number 18,841,000,000 which is obtained from the predicted fuel consumption data, shows the fuel consumption in the year 2008. For the conversion factor the amount of energy that is shown by 6.1 GJ is equal to around 158.98 of liter (Alberta 2007).

The number 8,726,500 is the number of light duty vehicles which are consuming only petrol in the year 2008 (Parsafar, Mirzaee et al. 2010). The baseline fuel consumption for the year that fuel economy standards will be implemented is then predicted by using the average of the annual fuel economy improvement (from section C2) by using equation 3.12. The calculation is as shown below:

$$BFC_{2013} = 2{,}159 \times (1 + 0.0418)^{(2013-2008)} \cong 2{,}649 \text{ liters/year}$$

The equation 3.13 is used to calculate the standards fuel consumption with a 5% improvement. The calculation is presented below:

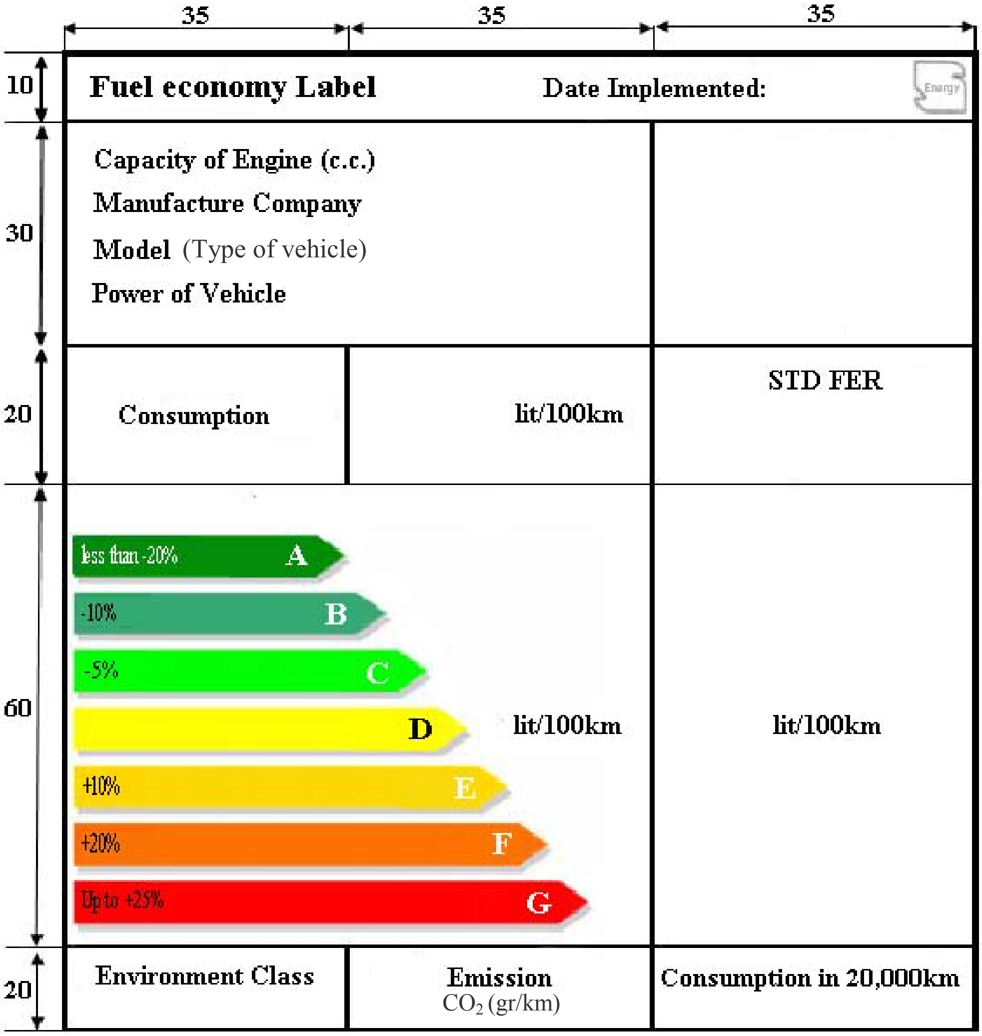
$$SFC_{MV} = 2{,}649 \times (1 - 0.05) \cong 2{,}517 \text{ liters/year}$$

APPENDIX D:
PROPOSED ECONOMY LABEL SPECIFICATIONS

D.1. Specification of energy labels

Words	Font	Style	Size	Color
Header				
Fuel economy Label (light duty vehicles)	Times New Roman	Bold	12	Black
Date	Times New Roman	Regular	12	Black
Energy agency logo	As it is indicated on the label	-	8×8 mm	Gray
Vehicle characteristics				
Capacity of engine	Times New Roman	Regular	12	Black
Manufacture Company	Times New Roman	Regular	12	Black
Model (Type of vehicle)	Times New Roman	Regular	12-10	Black
Power of vehicle	Times New Roman	Regular	12	Black
Body Information				
Fuel Consumption	Times New Roman	Regular	12	Black
Standard FER	Times New Roman	Regular	12	Black
Indicator				
A	Times New Roman	Regular, arrow	12	White, Green 088b0b
B	Times New Roman	Regular, arrow	12	White, Green 34a974
C	Times New Roman	Regular, arrow	12	White, Green 00fe04
D	Times New Roman	Regular, arrow	12	Black, Yellow fefe08
E	Times New Roman	Regular, arrow	12	White, Yellow fed40e
F	Times New Roman	Regular, arrow	12	White, Orange ec7902
G	Times New Roman	Regular, arrow	12	White, Red fe0002
Determined grade	-	A black arrow	-	Black 000000
Note				
Environment Class	Times New Roman	Regular	12	Black
Emission (CO_2, gr/km)	Times New Roman	Regular	12-10	Black
Consumption in 20,000 km	Times New Roman	Regular	12	Black

D.2. Fuel Economy Label (*English*) – *the measures are in mm*



Header:
Includes the date of implementation of program and responsible agency

Vehicle characteristics:
Represent the model, engine capacity and power of vehicle

Body Information:
Presents the fuel consumption of vehicle and standard fuel economy rating

Indicator:
A black arrow locates in front of determined FER and grade (A) means the highest fuel efficiency

Note:
Has more information about CO_2 emission of vehicle and fuel consumption annually

APPENDIX E
SAMPLE OF CALCULATION

E1 Fuel Economy Standards

E.1.1 Statistical Analysis

- Class 1

  Average FER

  $$FER_{2013} = 17.3 \times (1 + 0.0418)^{(2013-2008)} = 21.2 \qquad \ldots\ldots(E.1)$$

  Standard FER

  $$FER_{STD} = 21.2 \times (1 + 0.0418)^{(2013-2008)} = 22.2 \qquad \ldots\ldots(E.2)$$

- Class 2

  Average FER

  $$FER_{2013} = 15.8 \times (1 + 0.0418)^{(2013-2008)} = 19.3 \qquad \ldots\ldots(E.3)$$

  Standard FER

  $$FER_{STD} = 19.3 \times (1 + 0.0418)^{(2013-2008)} = 20.3 \qquad \ldots\ldots(E.4)$$

- Class 3

  Average FER

  $$FER_{2013} = 15.2 \times (1 + 0.0418)^{(2013-2008)} = 18.7 \qquad \ldots\ldots(E.5)$$

  Standard FER

  $$FER_{STD} = 18.7 \times (1 + 0.0418)^{(2013-2008)} = 19.6 \qquad \ldots\ldots(E.6)$$

- Class 4

  Average FER

  $$FER_{2013} = 13.5 \times (1 + 0.0418)^{(2013-2008)} = 16.6 \qquad \ldots\ldots(E.7)$$

  Standard FER

  $$FER_{STD} = 16.6 \times (1 + 0.0418)^{(2013-2008)} = 17.4 \qquad \ldots\ldots(E.8)$$

- Class 5

  Average FER

  $$FER_{2013} = 13.4 \times (1 + 0.0418)^{(2013-2008)} = 16.5 \qquad \ldots\ldots(E.9)$$

Standard FER

$$FER_{STD} = 16.5 \times (1 + 0.0418)^{(2013-2008)} = 17.3 \qquad \ldots\ldots(E.10)$$

- Class 6

Average FER

$$FER_{2013} = 12.6 \times (1 + 0.0418)^{(2013-2008)} = 15.5 \qquad \ldots\ldots(E.11)$$

Standard FER

$$FER_{STD} = 15.5 \times (1 + 0.0418)^{(2013-2008)} = 16.2 \qquad \ldots\ldots(E.12)$$

- Class 7

Average FER

$$FER_{2013} = 12.2 \times (1 + 0.0418)^{(2013-2008)} = 15.0 \qquad \ldots\ldots(E.13)$$

Standard FER

$$FER_{STD} = 15.0 \times (1 + 0.0418)^{(2013-2008)} = 15.7 \qquad \ldots\ldots(E.14)$$

- Class 8

Average FER

$$FER_{2013} = 13.2 \times (1 + 0.0418)^{(2013-2008)} = 16.2 \qquad \ldots\ldots(E.15)$$

Standard FER

$$FER_{STD} = 16.2 \times (1 + 0.0418)^{(2013-2008)} = 17.0 \qquad \ldots\ldots(E.16)$$

- Class 9

Average FER

$$FER_{2013} = 9.1 \times (1 + 0.0418)^{(2013-2008)} = 11.1 \qquad \ldots\ldots(E.17)$$

Standard FER

$$FER_{STD} = 11.1 \times (1 + 0.0418)^{(2013-2008)} = 11.7 \qquad \ldots\ldots(E.18)$$

- Class 10

Average FER

$$FER_{2013} = 10.2 \times (1 + 0.0418)^{(2013-2008)} = 12.6 \qquad \ldots\ldots(E.19)$$

Standard FER

$$FER_{STD} = 12.6 \times (1 + 0.0418)^{(2013-2008)} = 13.2 \qquad \ldots\ldots(E.20)$$

- Class 11

Average FER

$$FER_{2013} = 9.2 \times (1 + 0.0418)^{(2013-2008)} = 11.2 \qquad \ldots\ldots(E.21)$$

Standard FER

$$FER_{STD} = 11.2 \times (1 + 0.0418)^{(2013-2008)} = 11.8 \qquad \ldots\ldots(E.22)$$

E.1.2 Economic/engineering analysis

- Class 1 *(First design option)*

Present worth factor

$$PWF = \frac{1}{0.07}\left[1 - \frac{1}{(1 + 0.07)^{10}}\right] = 7.023 \qquad \ldots\ldots(E.23)$$

Operating cost

$$OC = \left[\frac{20000 \times 7000}{16.16}\right] = 10{,}263{,}366 \ Rials \qquad \ldots\ldots(E.24)$$

Life cycle cost

$$LCC = 81{,}168{,}000 + 10{,}263{,}366 \times 7.023 = 152{,}247{,}622 \ Rials \qquad \ldots\ldots(E.25)$$

Payback period

$$PAY = -\frac{(80{,}168 - 80{,}000) \times 10^3}{10{,}263{,}366 - 10{,}350{,}000} = 1.94 \ years \qquad \ldots\ldots(E.26)$$

- Class 2 *(Last design option)*

Present worth factor

$$PWE = \frac{1}{0.07}\left[1 - \frac{1}{(1 + 0.07)^{10}}\right] = 7.023 \qquad \ldots\ldots(E.27)$$

Operating cost

$$OC = \left[\frac{20000 \times 7000}{16.34}\right] = 10{,}166{,}962 \ Rials \qquad \ldots\ldots(E.28)$$

Life cycle cost

$$LCC = 94{,}212{,}000 + 10{,}166{,}962 \times 7.023 = 165{,}614{,}574 \ Rials \qquad \ldots\ldots(E.29)$$

Payback period

$$PAY = -\frac{(94{,}212 - 92{,}084) \times 10^3}{10{,}595{,}310 - 10{,}166{,}962} = 4.97\ years \qquad \ldots\ldots(E.30)$$

- Class 3 *(Last design option)*

Present worth factor

$$PWE = \frac{1}{0.07}\left[1 - \frac{1}{(1+0.07)^{10}}\right] = 7.023 \qquad \ldots\ldots(E.31)$$

Operating cost

$$OC = \left[\frac{20000 \times 7000}{17.04}\right] = 9{,}816{,}961\ Rials \qquad \ldots\ldots(E.32)$$

Life cycle cost

$$LCC = 115{,}064{,}000 + 9{,}816{,}961 \times 7.023 = 184{,}008{,}517\ Rials \qquad \ldots\ldots(E.33)$$

Payback period

$$PAY = -\frac{(115{,}064 - 112{,}936) \times 10^3}{9{,}816{,}961 - 10{,}227{,}009} = 5.18\ years \qquad \ldots\ldots(E.34)$$

E2 Impact due to the fuel economy standards and labels

E.2.1 Impact of the standards

E.2.1.1 Potential fuel savings

- Baseline fuel consumption

$$BFC_{2008} = \frac{18{,}840{,}775{,}440}{8{,}726{,}500} = 2159.03\ (liters/year) \qquad \ldots\ldots(E.35)$$

- Baseline fuel consumption in the year of standards implementation

$$BFC_{2013} = 2159.03 \times (1 + 0.0418)^{(2013-2008)} = 2650\ (liters/year) \qquad \ldots\ldots(E.36)$$

- Fuel consumption standards

$$SFC_{MV} = 2650 \times (1 - 0.05) = 2517\ (liters/year) \qquad \ldots\ldots(E.37)$$

- Initial unit fuel savings

$$UFS_S = 2650 - 2517 = 133\ (liters / year) \qquad \ldots\ldots(E.38)$$

- Shipment

$$Sh_i = (15{,}675{,}345 - 14{,}079{,}860) + 4{,}527{,}423 = 6{,}122{,}888 \qquad \ldots\ldots(E.39)$$

- Total fuel economy improvement

$$TI_{2013} = \frac{133}{2650} \times 100 = 5\% \qquad \ldots\ldots(E.40)$$

- Scaling factor

$$SF_{2013} = 1 - \left[(2013 - 2013) \times \frac{4.18}{5} \right] = 1.00 \qquad \ldots\ldots(E.41)$$

- Unit fuel savings

$$UFS_{2013} = 1 \times 133 = 133 \qquad \ldots\ldots(E.42)$$

- Applicable stock

$$AS_{2014} = 6{,}122{,}888 + 6{,}919{,}873 = 13{,}042{,}761 \qquad \ldots\ldots(E.43)$$

- Potential fuel savings

$$FS_{2013} = 6{,}122{,}888 \times 133 = 811{,}160{,}440\ liters \qquad \ldots\ldots(E.44)$$

E.2.1.2 Potential economic savings

- Capital recovery factor

$$CRF = \left(\frac{0.07}{1 - (1 + 0.07)^{-10}} \right) = 0.14 \qquad \ldots\ldots(E.45)$$

- Potential bill savings

$$BS_{2013} = 811{,}160{,}440 \times 7{,}000 = 5{,}678{,}123{,}080{,}471 \; Rials \qquad \ldots\ldots(E.46)$$

- Annual net savings

$$ANS_{2013} = 5{,}678{,}080{,}471 - (6{,}122{,}888 \times 0.14 \times 1.00 \times 662{,}400) = 5{,}110{,}310{,}772{,}424 \; Rials \qquad (E.47)$$

- Cumulative present value

$$PV(ANS_{2013}) = \frac{5{,}110{,}310{,}772{,}424}{(1+0.07)^{(2013-2008)}} = 3.18244 \times 10^{12} \; Rials \qquad \ldots\ldots(E.48)$$

E.2.1.3 Potential environmental impact

- Carbon dioxide reduction

$$CO_{2\,(2013)} = \frac{811{,}160{,}440 \times 2.4}{1000} = 1{,}946{,}785 \; tons \qquad \ldots\ldots(E.49)$$

- Sulfur dioxide reduction

$$SO_{2\,(2013)} = 811{,}160{,}440 \times 0.000074 = 60{,}026 \; kg \qquad \ldots\ldots(E.50)$$

- Nitrogen oxide reduction

$$NO_{X\,(2013)} = 811{,}160{,}440 \times 0.04476 = 36{,}307{,}541 \; kg \qquad \ldots\ldots(E.51)$$

- Carbon monoxide reduction

$$CO_{(2013)} = 811{,}160{,}440 \times 0.1145 = 92{,}877{,}870 \; kg \qquad \ldots\ldots(E.52)$$

E.2.2 Impact of the label

E.2.2.1 Potential fuel savings

- Baseline fuel consumption

Baseline fuel consumption for labels is the same as standards fuel consumption, the calculation (E.35) gives the sample.

- Baseline fuel consumption in the year of standards implementation

Baseline fuel consumption for labels in the year of standards implementation for labels is the same as standards fuel consumption, the calculation (E.36) gives the sample.

- Label fuel consumption

$$LFC_{MV} = 2517 \times (1 - 0.05) = 2391\ (liters / year) \qquad \ldots\ldots(E.53)$$

- Initial unit fuel savings

$$UFS_S = 2517 - 2391 = 126\ (liters / year) \qquad \ldots\ldots(E.54)$$

- Shipment

Similar to $(E.39)$

- Applicable stock

Similar to $(E.43)$

- Potential fuel savings

$$FS_{2013} = 6{,}122{,}888 \times 126 = 770{,}602{,}418\ liters \qquad \ldots\ldots(E.55)$$

E.2.2.2 Potential economic savings

- Capital recovery factor

Similar to $(E.45)$

- Potential bill savings

$$BS_{2013} = 7{,}706{,}027{,}418 \times 7{,}000 = 5{,}394{,}216{,}926{,}448\ Rials \qquad \ldots\ldots(E.56)$$

- Annual net savings

$$ANS_{2013} = 5{,}394{,}216{,}926{,}448 - \left(6{,}122{,}888 \times 0.14 \times 1.00 \times 662{,}400\right) = 4{,}854{,}795{,}233{,}803\ Rials \quad (E.57)$$

- Cumulative present value

$$PV\left(ANS_{2013}\right) = \frac{4{,}854{,}795{,}233{,}803}{\left(1+0.07\right)^{(2013-2008)}} = 3.4614 \times 10^{12}\ Rials \qquad \ldots\ldots(E.58)$$

E.2.2.3 Potential environmental impact

- Carbon dioxide reduction

$$CO_{2\ (2013)} = \frac{770{,}602{,}418 \times 2.4}{1000} = 1{,}849{,}446\ tons \qquad \ldots\ldots(E.59)$$

- Sulfur dioxide reduction

$$SO_{2\ (2013)} = 770{,}602{,}418 \times 0.000074 = 57{,}025\ kg \qquad \ldots\ldots(E.60)$$

- Nitrogen oxide reduction

$$NO_{X\ (2013)} = 770{,}602{,}418 \times 0.04476 = 94{,}492{,}164\ kg \qquad \ldots\ldots(E.61)$$

- Carbon monoxide reduction

$$CO_{(2013)} = 770{,}602{,}418 \times 0.1145 = 88{,}233{,}977\ kg \qquad \ldots\ldots(E.62)$$

E3 Expected market transformation

- Present average fuel economy rating

$$FER_{PAF} = 10.9 \times \left(1+0.0418\right)^{(2013-2008)} = 13.3 \qquad \ldots\ldots(E.63)$$

- Standards average fuel economy rating

$$FER_{SAF} = 13.3 \times \left(1+0.0418\right)^{(2013-2008)} = 16.32 \qquad \ldots\ldots(E.64)$$

- Labels average fuel economy rating

$$FER_{LAF} = 16.32 \times \left(1 + \frac{45\%}{7}\right) = 17.37 \qquad \ldots\ldots(E.65)$$

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